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A Translation Of

PLANT PHYSIOLOGY

(FIZIOLOGIYA RASTENII)

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PLANT PHYSIOLOGY

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CONTENTS

CONTENTS (continued)

VLADIMIR IVANOVICH PALLADIN

(On the 100th Anniversary of His Birth)

On July 11 of this year, one hundred years will have passed since the birth of the great Russian plant physiologist and biochemist, V. I. Palladin. The main accomplishment in the life of V. I. Palladin was the development of the theory of respiration which was much ahead of its time and, in its basic outline, was the prototype of the modern theories in this area. His great accomplishment was ahead of biological science, in general. However, Russian science is no less obliged to him as the founder of the large and famous school of our plant physiologists and biochemists: such names as S. P. Kostychev, A. A. Rikhter, N. A. Maksimov, S. D. L'vov, N. N. Ivanov, O. A. Val'ter, D. A. Sabinin, N. A. Monteverde, V. G. Aleksandrov, T. A. Krasnosel'skaya, A. M. Sheloumova, M. P. Korsakova, and many others are among his students and followers.

Also, how many of our scientists, pedagogs, and practical workers were, are, and will be those who, although they did not work directly with V. I. Palladin, heard his lectures, studied his textbooks on the anatomy and physiology of plants, and, having become interested and inspired by his works, worked and are working in the most variable fields of plant physiology, biochemistry and other divisions of biology.

V. I. Palladin was born on June 11, 1859, in Moscow. He entered Moscow University in 1878 after completing the gymnasium, selected botany as his specialty, and began to work experimentally under K. A. Timiryazev while still a student. When V. I. Palladin completed the university course in 1882, he was kept on the faculty by K. A. Timiryazev as a form of stipend for preparation towards professorial activity.

In 1886, V. I. Palladin wrote a master's dissertation, "The Importance of Oxygen for Plants", and from that time until 1901 was in turn professor at the Agricultural Institute in Novo-Aleksandrovskaya (1886-1889). Khar'kov University (1889-1897), and Warsaw Polytechnic Institute (1897-1901).

In 1901 V. I. Palladin moved to St. Petersburg to the position of Director of the faculty of plant physiology in the University and Professor of the Upper Women's (Bestuscheff's) courses.

In 1906, Vladimir Ivanovich was made a corresponding member of the Russian Academy of Sciences, and in 1914, and active member. He left the faculty of Petersburg University in 1914, and in his subsequent work was connected primarily with the Academy of Sciences. The Petersburg period was the most productive in V. I. Palladin's work. The Palladin school of Russian plant physiologists and biochemists, which was mentioned above, was also formed here.

V. I. Palladin developed his celebrated theory of respiration at this same time.

There were various hypotheses on the nature of the process of respiration prior to the beginning of V. I. Palladin's work in this area.

However, the most widespread was the view of respiration as a process of slow combustion, formed by Lavoisier: "Thus, respiration is actually a combustion, although very slow, in essence quite similar to the burning of coal."

Thus, Lavoisier's hypothesis suggested a direct oxidation of organic substances with oxygen with the formation of CO_2 and H_2O. The substance of this hypothesis could be represented in the equation:

$$(CH_2O) + O_2 \rightarrow CO_2 + H_2O.$$

However, biologists, in particular V. I. Palladin, could not reject the fact that the majority of the organic substances, and especially the sugars, were not oxidized directly on simple contact with oxygen. And if there also exist stimulating reasons, for example in the form of a "fuse" such as a high temperature, for this oxidation, then the combustion proceeds rapidly, spontaneously, and only yields with difficulty to systematic regulation.

Consequently it would be necessary, in order to understand the substances of the process of respiration, to first explain the biological systems which could activate oxygen or organic substances making their interaction possible.

Secondly, it would be necessary to understand the systems regulating the rate and direction of the process in direct conformity to the unstable and changing demands of the activity of the organisms. V. I. Palladin set as his goal the solution of precisely these questions.

A. N. Bakh made one of the first attempts in this direction, in which attention was directed toward the mechanism of the biological activation of oxygen. In 1892 A. N. Bakh presented a theory according to which there exists in plants self-oxidizing substances, oxygenerators, which form peroxides, "peroxidases", when added to oxygen. The oxygen of the peroxides possesses a high oxidizing potential and, as A. N. Bakh thought, can be transmitted to the oxidized respiratory substrates with the help of enzymes, peroxidases. A. N. Bakh's theory played a large and positive role in the development of the study of respiration, although, as later explained (with the important service of V. I. Palladin) the question of the activity of oxygen and its transfer upon the reaction of the biological oxidation is only a part of the much more complexmechanism of respiration.

V. I. Palladin used the Bakh theory in the first period of his work, but expanded its hypothesis on the presence in plants of special transmitters of oxygen, chromogens (A), capable when introduced of oxidizing with oxygen with the help of oxidase and of forming pigments (AO), which in their turn transfer oxygen to the oxidizing substrates (C), dioxidizing themselves and reforming chromogens (A) ("A Theory of Respiration of Plants, 1909). A similar concept could be represented by the equation:

$$O_2 \rightarrow A \rightleftarrows AO_2 \rightarrow (C) = CO_2$$

V. I. Palladin's theory on the respiratory chromogens was a bright side of his investigations. However, V. I. Palladin himself found insufficiencies in it and substituted the concept which is already the prototype of the modern teaching of respiration.

In his further work, V. I. Palladin collided with the fact that the enrichment of several organisms (for example yeasts) with extracts, rich acceptors of oxygen, chromogens, did not give these organisms the ability to move from alcohol fermentation to oxygen respiration.

In addition to this, the fact that, organisms give off CO_2, both in anaerobic and aerobic respiration must be considered, although according to the then universal view, CO_2 would have had to be only a product of the direct oxidation of the respiratory substrates with oxygen of the atmosphere.

These facts led V. I. Palladin to assume that the oxidation of organic substances can be accomplished not only in respect to the compounds of carbon with the external oxygen, but also with internal molecular oxygen and also in respect to the elimination of hydrogen from the oxidized molecule. However, for such an oxidation of the respiratory substrates in the cells, there must be, first of all, active acceptors of hydrogen and, secondly, sources of internal oxygen. V. I. Palladin gave the role of hydrogen acceptors to the respiratory pigments themselves, to which he devoted so much attention in his previous works and which, as he thought earlier, were the acceptors and transmitters of oxygen. The acceptors of hydrogen are activated with the help of the enzymes of reductases (or dehydrases).

He considered water to be among the sources of internal oxygen.

In accordance with the new theory formed in this manner, the molecules of respiratory material (for example, $C_6H_{12}O_6$) reacting with molecules of water and acceptors of hydrogen, the respiratory pigments (R), decompose the molecule of carbon dioxide with the formation of reduced forms of the respiratory pigments (RH_2) without any sharing of the external carbon dioxide. V. I. Palladin described this part of his propositions with the equation:

$$C_6H_{12}O_6 + 12R + 6H_2O = 6CO_2 + 12RH_2$$

Thus, V. I. Palladin first, being in this connection the predecessor of Villand, developed a hypothesis of the important role of the transmittal of hydrogen with the help of reductase (dehydrase) in the respiratory reaction and with the assistance of water. These hypotheses were widely developed in modern theories of respiration and are some of the cornerstones of teaching on respiration. The second link in the reaction of respiration, according to the theory of V. I. Palladin, is included in the oxidation of the hydrogen acceptored by the chromogens by oxygen from the external environment, activated and acceptored by oxidases. With this, the chromogens giving off hydrogen are again converted into respiratory pigments. V. I. Palladin represents this part of the process by the equation:

$$12RH_2 + 6O_2 = 12R + RH_2O$$

This part of V. I. Palladin's theory received further development in modern research on the activation of oxygen and on the participation in it of terminal oxidases transmitting electrons and hydrogen from a series of dehydrases to the activated oxygen and is, in the end, complex and as puzzling as the earlier process of respiration.

V. I. Palladin, elaborating on this substitute theory of respiration, gave a great deal of attention to the study of a combination of enzymes of living cells and the role of protoplasm as a regulated beginning guaranteeing the coordinated and orderly work of the enzymes and the course of the vital reaction. V. I. Palladin contrasted the activity of the enzymes in living and dead cells in order to solve this question. At the same time he laid the foundations of the modern technical biochemistry, successfully developed for us by Academician A. I. Oparin.

These hypotheses, which were developed by V. I. Palladin, on the theory of plant respiration are now common and widely held, and sometimes seem to us to be customary and obvious, as many rough theories which remain widely spread and popular. This sometimes interferes with a full appreciation of the actual importance of V. I. Palladin's works and concepts; but these works and concepts are excellent not only because of their final results, and not only because they added to the development of science, but also because of their process of development and stabilization. Precisely because of this their singularity is well felt and understood when again and again the works of V. I. Palladin himself, his predecessors, contemporaries and followers are reviewed in succession.

A. A. Nichiporovich

PROBLEMS OF PLANT PHYSIOLOGY IN LIGHT OF THE DECISIONS OF THE XXI CONGRESS OF THE COMMUNIST PARTY OF THE SOVIET UNION

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The December Plenum of the Central Committee of the Communist Party of the Soviet Union and the XXI Congress of the Communist Party of the Soviet Union placed great tasks before agriculture in our country.

We quote from the "Materials of the Extra XXI Congress of the Communist Party of the Soviet Union" (Gospolitizdat 1959, Page 201):

"In the future, the seven-year tasks of agriculture are such that we will attain growth in agricultural production in order to meet the demands of the population in necessary food products, to sharply increase the resources of agricultural raw materials so that the population will be guaranteed food products of wide assortment and high quality, and to meet all other demands of the government for agricultural products."

In connection with this, "in 1959 to 1965 there is specified an increase in the volume of the total production of agricultural goods of 1.7 times. The average annual increase in production is 8 %". (same, page 25).

All strength must be mobilized and all possibilities used in fulfilling these goals.

Work in the area of plant physiology must play an important role in this.

The basic object of agriculture is the plant, and it is clear that the successes of agriculture can be larger the better we understand the nature of the plant as a living organism, its demands for conditions of external environment and its response to changes in these conditions.

K. A. Timiryazev [1] named plant physiology as one of the bases of rational agriculture. Actually plant physiology has played a colossal, literally revolutionary role in its time in the progress of agriculture.

After the beginning of the nineteenth century when the bases of photosynthesis and mineral plant nutrition, including the feeding of atmospheric nitrogen with the help of tuber-forming bacteria, had been studied, the agriculture of a number of countries was shifted to a new technique on a new technical level: the rotation of crops, including legume plants, and the wide use of fertilizers were introduced. As a result of this the average harvest of basic crops in a number of countries increased three to four times within a few decades [2].

How can the basic merit of plant physiology and agrochemistry be included in this ?

Plant physiology as an exact science has existed little more than one hundred years, and agriculture is one of the most ancient branches of the productive activities of man. In a number of countries with an ancient culture, hundreds and even thousands of years ago a technique of culture for such plants as wheat, rice, and sweet potatos existed, and these crops gave such high yields that they can also serve as models for modern agriculture.

For proof of this, it is sufficient to bring to mind the ancient agriculture of China.

One cannot reach on this basis the conclusion that a practical national experiment in such a business as agriculture is a fully adequate means for the management of high yield plant crops, because for this the knowledge of all the details and particulars of the process of the plant life is certainly not of sole importance; the strength of a national experiment is in its size, and because there is always the chance in such massive work that whoever observes and receives positive action of these or other conditions and methods will strengthen previous results in further work and then will stand on the common inheritance.

Actually the experiment of life suggests that the massive practical experiment is of enormous value in progress in any field and, in particular, in the area of agriculture. Its development, promotion, rapid use and expansion must be a business of literally national importance. However, it is also clear that the less the practical experiment is based on exact scientific data and knowledge, the more limited are its possibilities, and it is completely without doubt that massive practical experiments and scientific investigations in the field of agriculture must be established separately, and must mutually enrich each other.

The following example illustrates this. If we speak of fertilizers, they were applied hundreds and thousands of years ago in those countries with an ancient agriculture. However, these were only local fertilizers: manure, feces, mud, ash, peat, and they were applied on the basis of their positive action without understanding of the nature of their action. It is clear that good, and even excellent, results could be obtained in individual or limited cases in spite of this limited base, but the average level of agriculture was still low.

The development of plant physiology and agrochemistry in the nineteenth century made it possible to expand without limits the material base for the production of specialized fertilizers. The industry began to produce saltpeter, ammonium salts, phosphorous and potassium fertilizers, lime, etc., widely. The availability of specialized fertilizers made it possible to vary and refine the technique of their use to correspond to the characteristics of the soils and the demands of the plants.

All of this made it possible to apply fertilizers in broad doses and to take this measure in mass, and profitably.

The introduction of crop rotation with a rational plant scheme was of no less importance.

So modern agriculture emerged on a scientific base which guaranteed its progress for many decades, and even now not only are new principle developments necessary for the increase of the yield, but also the broad, practical realization of the already available achievements of science and the data of the practical experiment.

However, this by far does not indicate that science has exhausted its possibilities in this field. In fact, it is not difficult to obtain a high yield in individual cases with the present level of knowledge and on the basis of the ability of the practical experiment. One can also obtain very high yields using such means as deep plowing of the soil with layered application of high doses of fertilizers, with the use of irrigation and with individual care of plants. There is a specific idea in this: first, one can determine the potential yield of plants by such means, and this must serve as the final goal of all experimental and practical works. In addition to this, such means of plant culture can be agriculturally useful in a number of cases, for example when culturing valuable plants, when propagating variety material, and in those cases where the provision of effective strength is high.

However, it is not completely true that this is necessary for the progress of agriculture on a broad scale. The task of scientific investigations is included in this in order to establish the principal importance of this or other factors, and to find the conditions of its highest effectiveness so that, in finding its broad application, the method or means is also a means for increasing the harvest, the productivity of work and the profitability of agriculture; all of which coincides with the decision of the XXI Congress of the Communist Party of the Soviet Union, in which it was stated that, "the Congress considers as an important aim of the Seven-Year Plan a significant increase in the productivity of common labor". (page 150)

Thus, there are before us many large tasks if one speaks of a system providing for the mineral nutrition of plants. We will point out several of them.

The use of soil fertilizer and the effectiveness of its use is strongly limited by the inadequacy of the water supply that is characteristic for large areas of the Soviet Union, especially in the zones with potentially highly fertile soils. Of course the main task of the work in these regions is the battle for moisture. However, insufficient moisture will develop, to a greater or lesser degree, even where there exists a possibility for irrigation, and where

all of the other possibilities (holding snow, well-timed treatments, seeding and others) have been used. Therefore, special broad investigations on the best use of soil fertility, on increasing the effectiveness of fertilizers in the zone of limited water supply, on softening the effect of inadequate moisture with the help of fertilizers, and on increasing the resistance of plants to an inadequate moisture supply are some of the important tasks facing our agriculture. The success in solving this task is determined to a significant degree by the degree of speed and effectiveness to which the physiological bases of the interaction between the processes of mineral nutrition and the water regime of plants will be studied. Results have already been obtained in this direction suggesting significant prospects for progress, in particulary the possibilities of increasing the drought resistance of plantings [3].

Especially important here is the application of small doses of fertilizers with seeds and planted material so that the beginning growth of plants is forced and the complete and best use is made of the favorable period, from the point of view of moisture, in the spring and the beginning of summer.

The prospect is for the use in these cases, of trace elements [4] in particular those containing boron, which have a positive effect that can be very strong, but a negative effect, insofar as increasing the osmotic concentration of the soil solution, that is small. An especially strong effect in increasing the heat resistance of plants is shown by the trace elements zinc and molybdenum [5]. They strengthen the accumulation of organic acids, which brings about a protective reaction against high temperatures in plants.

However, the problems that also face plant physiology in works on the improvement of the system of plant fertilizers in the zones or conditions of sufficient moisture where high harvests are possible in the order of 30 to 40 centners per hectare and higher for grains, 500 to 700 centners per hectare and higher for tuber and root plants, and 600 to 750 centners and higher for the green vegetation of corn, are no smaller.

Corresponding to the similar agricultural yields are biologicalyields of 12 to 15 tons and higher of normal dry mass [6,7] and for this,plants must take from the soil 200 to 300 kg or more of nitrogen, the same of potassium, and 50 to 100 kg of phosphorous. It is not an easy task to guarantee to the plants the possibility of assimilating such quantities of the basic nutrient substances with a high coefficient of use of their action, particularly on soils which were originally poor and with a low concentration of humus. This task can be fulfilled only in proportion to the basic preplanting application of fertilizers in easily soluble forms.

Along with the normal positive effect of mineral fertilizers, such negative effects as an increase in the loss of fertilizers through leaching, a decrease in the coefficient (portion) of use of fertilizer from the soil and the coefficient of the physiological effect of nutrient elements assimilated by the plants, are also observed often with an increased dose of mineral fertilizers applied prior to planting. The latter negative effect is shown by the fact that, with increased doses of fertilizers and soil moisture, increased growth of the leaf and straw with a deterioration in the relationship between grain, root and tuber plants on one hand and leaf with straw on the other are often observed. Often an excessive unproductive increase in the yield of the percent concentration of nitrogen, and especially in the harmful nitrogen in beet roots, potato tubers, etc.,is observed.

The indicated effects are dependent on the fact that the optimal relationship between the elements assimilated by the plants and between the quantities of fertilizers and accompanying conditions of the environment (acidity, moisture, osmotic concentrations of the soil solution, etc.) are upset with increased doses of fertilizers.

Some unbalancing of the physiological processes plays a negative role: the quantity of nutrient elements passing through into plants is increased with an increased dose of fertilizers, but the ability to convert them into necessary compounds remains constant. This leads to the accumulation of intermediate, only partially valuable, products of the metabolism of substances and in one degree or another to the disorganization of the normal life activity.

To guarantee plants in plantings, especially on soils which were originally insufficiently productive, with a good supply of nutrients and, in addition, not disturb the harmonious relations between the elements of nutrition and the physiological processes is both an important and a difficult task.

First of all, a normal increase in the stock of soil fertility in poor soils by enriching them with humus and easily held forms of the nutrient elements is necessary for the successful solution of this problem. Assimilable forms of nutrient substances must gradually be created in proportion to the microbiological activity. Besides this, the application of fertilizers in easily assimilable and active forms under plowing with planted material in the feedings is necessary.

This is the general scheme of the conditions and demands necessary for obtaining high yields.

However, for this there is a large variety of concrete conditions and their combinations, and the variable demands of the plants themselves. These must not only be studied in detail, but also must be recognized and understood in each concrete case, at every moment of the vegetation period, and must be satisfied in the best way in order to justify the input of work, fertilizers and the means of productions by high response of the plants at any level of progress in the work of increasing the yields.

An extremely important step in this direction is the development of means for the rapid and accurate diagnosis of the demands of plants for mineral nutrients and the physiological conditions of plants determined by these factors [8,9] and also the development of highly effective means for guaranteeing plants the optimal nutrition throughout their growth and development, where the layered and local applications of fertilizers and the application of foods in strict conformity with demands of the plants, which change in ontogeny and in conformity with their physiological condition, are especially effective [10-15].

In the zones where high soil fertility is combined with good moisture (for example, in the Kuban and the foothill area of the north Caucasus with chernozem soils), of primary importance is the question of the rational management of the microbiological activity of the soils for the best mobilization of the nutrient substances from the stock of high soil fertility in conformity with those demands of the plants in planting, the satisfaction of which can guarantee that high yields will be obtained.

However, here also the use of small doses of fertilizers, particularly trace elements, can guarantee the most effective use of the high soil fertility by the plants by activating the physiological processes. The complex work of plant physiologists and microbiologists is especially necessary in these conditions.

All of these questions are being strongly developed both by us and by those outside our borders at the present time, but they require even greater attention. One of the important tasks of plant physiology lies in this direction.

Thus the achievements of plant phsyiology and agricultural chemistry have already shown a fundamental, revolutionary effect on the progress in the area of agriculture, giving to agriculture such powerful means for increasing yields as the application of fertilizers, the rational use of the stocks of normal soil fertility, and the introduction of crop rotation.

However there are still many questions in this area, the solving of which would yield great possibilities for progress in agriculture.

However, there are, in addition to this, other important areas where broad physiological investigations can and are rendering great services to agriculture which were and are being planned. One of these is the area of the study of the possibilities and means for the best management by different forms of plant nutrition, the process of their carbon nutrition, and photosynthesis.

In the process of photosynthesis, plants form 90 to 95% of the normal mass of the yield and, converting the energy of the sun's rays into it, accumulate the valuable part of the yield, the potential chemical energy.

The role of photosynthesis as a decisive factor in plant nutrition and the formation of yields was known long ago, but only recently have the means for the control and management of these important forms of plants nutrition in agricultural practice been developed.

Thus, studies of the relationship of the size of yields to the area of the leaves in planting and the optimal paths of growth have been formed, where the area of the leaves is sufficiently large to absorb much of the energy of the sun's radiation and to form the maximum possible quantity if organic substances, but not an excessive quantity, which would impair the conditions of photosynthesis, for which good light conditions are necessary if it is to go to completion [6, 7, 16].

The development of conditions and means guaranteeing the growth of the area of leaves in plantings in the optimal manner is an important task in the battle for high yields, because the leaf area in plantings is often two to four times smaller than the optimal and, consequently, lower yields are received. However, in addition to the development of practical means to quarantee the growth of the leaf area in plantings in the optimal manner, it is necessary for plant physiologists to work toward specifying the types of optimal

graphs for the various crops (especially crops of grain, root and tuber plants, and vegetative mass), for various geographical zones with differing light intensities and various moisture regimes, and especially for various backgrounds of fertility. Thus, the indicators of the optimal area of the leaves in plantings are greater in areas with very high soil fertility, but it is necessary to specify these relationships. Apart from this, the strengthening of work directed at increasing the intensity and productivity of the photosynthesis process, that is, increasing the productivity of each square meter of leaf area that is dependent on the conditions of plant culture, is also necessary. Thus, in poor conditions each square meter of the leaves of plants forms one to two grams of dry mass of harvest per day; more often the indicators correspond to 5 to 6 grams of dry mass per square meter of leaves per day for dicotyledons and 8 to 10 grams for grasses. A detailed study of the nature and mechanism of photosynthesis suggests that the theoretically possible productivity of the process is even 25 to 30 grams of dry mass of harvest per square meter per day.

Investigation into the methods of increasing the productivity of plant photosynthesis to bring it up to the theorectically possible level is an important task facing modern plant physiologists.

Investigations in recent years have also established the fact that the qualitative direction of photosynthesis has an important role in the physiology of plants and in the path of their growth and development. The composition of the direct products of photosynthesis is different (carbohydrates, amino acids, organic acids) and changes in relation to the type of physiological condition of the plants and to the nutrition conditions and environment.

Thus, in turn there is the task of the management not only of the quantitative, but also the qualitative side of photosynthesis [19-19a].

The discovery of special varieties of agricultural plants with high photosynthetic activity and productiveness is necessary for increasing the productivity of plants. Therefore, the work of selection must be accompanied by fixed evaluation of the selection materials on the photosynthetic activity.

The discovery of varieties with high photosynthetic activity is important for many other reasons: such varieties must effectively use the background of high fertility and increased doses of fertilizers because the assimilation of nitrogen, phosphorus, sulfur and other elements of mineral nutrition in the first place demands real energy, the source of which is photosynthesis; secondly, the assimilation of elements of mineral nutrition includes not only their penetration into the organs, tissues and cells of the plants, but also their inclusion in the composition and processes of metabolism of organic substances formed in the process of photosynthesis. Thus the intensive use of the elements of mineral nutrition is possible only with the high photosynthetic activity of plants.

Every kind of increase of photosynthetic activity of plants is important also as a means for the most productive use of the moisture factor, which very often is one of the factors that limits the dimensions of the yields most severly. The moving force of photosynthesis and transpiration is the absorbing of the energy of the sun's radiation by the chlorophyll of the leaves.

The lower the absorption of energy used in photosynthesis, the more goes into the heating of the leaves and transpiration, and vice versa. Thus, when we work for an increase in the intensity and productivity of photosynthesis, we are also working at the same time for the most productive use of the amount of moisture, which is often limited. It is theoretically possible [6] to increase the coefficients of productivity of the moisture used by plants, in comparison to the modern indicators, by 4 to 5 times and to bring up the transpiration coefficients to 100, instead of the 400 to 600 which is usual in modern plantings. When working to increase the productivity of photosynthetic apparatus of plants, we must first of all direct our endeavors to overcoming the factors and conditions limiting its intensity, which potentially can be very high.

We will indicate several of these limiting factors. The beginning and important reaction of the process of photosynthesis is a photochemical reaction. Here the molecules of chlorophyll absorb photons (quanta of light) and acquire the ability to transfer electrons and hydrogen through the system of donors and acceptors from water with the reduction of CO_2 [20,21].

The mechanism of the process of photosynthesis is such that for the conversion of each assimilated molecule of carbon dioxide to organic substance, it is sufficient to absorb 8 photons or quantas of energy. And actually eight-quanta input of photosynthesis was observed in short-term laboratory experiments under the maximum favorable conditions. The coefficient of use in photosynthesis of the absorbed energy approaches 28%

in these cases. Only part of the absorbed photons is realized as work used in photosynthesis in the normal field conditions. Their large quantity "deteriorates from idleness"; their energy is simply converted into heat. In the end of quanta input in the field case is 100 and more photons per molecule of assimilated CO_2, but the percent of use of the absorbed energy is 1 to 2 and in good cases, 5 to 6. The remaining portion of the absorbed energy goes into the heating of leaves and evaporation.

One of the reasons for the large discrepancy between the theoretically possible photosynthesis and its actual production is found in the limited "permeability" of the fermenting system of the photosynthetic apparatus of plants. The enzymes are not able to digest all of the original products formed as a result of the primary photochemical reaction with average and high intensities of light. A detailed study of the mechanism of the process of photosynthesis and the discovery of means and possibilities for its intensification, in particular the intensification of the dark enzyme reaction of the process, is necessary.

The second circumstance limiting photosynthesis is found in the fact that it can proceed with high intensity only in the case where the products of photosynthesis are quickly removed from the photosynthesizing cells and from the leaves into other tissues and organs and used there in the growth processes or in the accumulation of reserves.

The movement of substances in the plant is a complex physiological process demanding for its accomplishment the consumption of energy and favorable conditions. It depends very much on the conditions of environment and on the physiological conditions of the plants [22-25].

Thus, an insufficient water supply retards the outflow of assimilates from the leaves and inhibits photosynthesis. Similarly, the outflow and utilization of assimilates is sharply strengthened with a good water supply and strengthened mineral nutrition [25].

The study of the movement of substances in plants received broad development quite recently in connection with the use of the extremely favorable method of tracer atoms. These possibilities must be widely used for further strengthening of work in this important area.

The study of the physiology of the processes of growth is especially important for increasing the productivity of plants, because they are the final and deciding links in the formation of the yields where the products of plant nutrition are converted in the cells, tissues and organs of the plants, into the reserve substances of the organs, and, in the end, result in the real yield.

The characteristic manifestations of plant growth as a whole are such that in the first stage all nutrient substances are used in the growth of the feeding (roots, leaves) and transferring (stems) organs. Subsequently, the growth of these organs is practically suspended and their work is directed at guaranteeing the growth of the reproductive (fruits, grain) or storage (roots and tubers, bulbs, etc.) organs. The final stage of growth in the majority of plants is the dying of leaves, stems, and for annuals, the roots, and the transfer, by them, of the maximum quantity of their plastic substances to the growth and increase of reserves in the reproductive and storage organs.

In order to obtain large and high yields, it is necessary that all stages of growth proceed most intensively and that all stages take turns and are completed most fully with the maximum outflow of the plastic substances of the biological yield into its agriculturally valuable parts.

The path and direction of the processes of growth are very dependent on the conditions of the environment and plant nutrition. Therefore, there are many important questions and tasks in the means for the development of procedures for the most effective management of the growth processes facing physiologists.

For this, the following points must be kept in mind: the reserve of the photosynthetic powers of the plant leaves could guarantee the formation of spikes, ears, grain, tubers, and roots, three to four times as heavy as those of the present time. If this is not observed, then the consumption in these organs of the products of photosynthesis is also limited to a significant degree from the limiting of the growth processes.

At the present time we still do not know whether or not the characteristics and rules of plant growth limit the number of grains in a spike or the size of the grain; on what depends, and to what degree can be changed, the tempo of propagation and growth in the dimensions of the cells and tissues of potato tubers, beet roots, succulent fruits, and consequently, up to what dimensions can the tubers, roots, and fruits be carried;

we still do not adequately know the rules of growth determining the number of ears on a stem of corn and up to which indicators or how it can be increased. In connection with this, there is an important task facing the plant physiologists in the detailed study of the rules of plant growth and the conditions for the possibility of obtaining 3 to 4 to 5 times more grain and tubers, 3 to 4 times more weight in roots, etc. on the base of the work of each square meter of leaves in planting.

The points described above suggest that all the physiological processes of plants take place in a strong interrelationship and are interdependent. Also, the high productivity of the work of the plant can be guaranteed not only when we study, know, and attempt to manage the separate processes, but also when we study, know, and manage the activity of the plant as a unified whole, accomplishing the complex unitary system of the interrelated and interdependent processes. This also concerns the interdependency of all of the internal processes and the interrelation and interdependency of the activity and work of the different organs of the plants, having in mind their specific share in the processes of feeding, in biosynthesis, and also the correlated relations in their growth, etc. [25-28].

A detailed study of the activity of the plant as a unified whole [27] is a serious obligation of plant physiologists who take part in research to increase the yield of agricultural crops and agricultural productivity.

As we stated above, one of the important environment conditions determining the activity, growth, and yield of plants is the factor of moisture, and therefore, work on the study of the best guarantees of moisture for plants has special importance for many regions of the USSR [29]. Thus, the method developed by Soviet physiologists for the early diagnosis of the demands of plants for water by physiological indicators makes it possible to take steps for the change in the regions of agricultural irrigation, from the standard agricultural techniques to mobile, differentiated ones in which the means of handling plants in each separate case is based on their physiological demands [29,30].

The development of means of "atmospheric irrigation" with the help of automatically activated rain equipment, made possible by the use of a modification of the microclimate (increased relative humidity of the air and its decreased temperature), strengthens the growth processes and increases the yield of such valuable plants as tea [31].

The problem of the study of the individual development of plants (ontogeny) is another of the important tasks which face physiologists.

Changes in the phases of growth, of which we spoke above, proceed as a result of great qualitative chances of plants and, in particular, as a result of passing through the vernalization stage [32], and as a result of the reaction of plants to various photoperiods.

There is a change, in relation to the passage of the plants through the stages of individual development, not only in their ability to transfer from vegetative growth to the formation of reproductive organs, but also in the abundance of fruits, the formation of tubers, succulent fruit, etc. Their relation to the conditions of the external environment (for example, winter resistance) and the tendency of potatoes to degenerate are both sharply changed. Discoveries in the area of individual plant development are widely used in work on selection (staged analysis and selection of parents for crossing, for division into districts, for the disclosure of winter-resistant varieties, etc.). However, the tasks of plant physiologists have far from disappeared from this area.

The bases of development of perennial plants must be studied in still more detail and the new stages of individual plant development, in addition to the stages of vernalization and light, must also be studied in detail. There are also great possibilities for solving such acute and difficult problems as those of the resistance of plants to insufficient moisture and to winter [33] in studying the development of the means of management by the plant.

The influence on plants in the early stages of ontogeny (embryo and in the seeds, shoots) is of great interest. The organism in this condition is especially subject to various influences. The most variously formed influences, apart from the means of vernalization and stratification, are possible here, such as the increased plant resistance in the later phases of growth [34,35], giving the plants a lead in growth and development that makes it possible for them to use the favorable conditions of spring and the beginning of summer and to resist better or even forestall the difficult conditions of the later period [36].

An important stage of the individual plant development is the period of ripening, the completion of the activity of annual plants, and the period of rest for perennials. Both the dimensions and quality of the yield of the first period depend on how successfully and completely it proceeds.

The approach and full value of the condition of rest to a very strong degree determines, for example, the overwintering of plants [35a,36,37]. For good overwintering of perennial plants, for example apple, it is necessary for them to cease the growth processes towards winter and to move over into the condition of rest and also to receive hardening by low temperatures.

The depth and full value of passing through this and the other process depend on a number of conditions and in particular, on the condition of moisture, the system of feeding, and temperature (high moisture, increased temperatures, strengthened nitrogen feeding in the second half of the summer are unfavorable for both these processes). In an overwhelming number of cases the conditions are such that either this or the other process proceed incompletely and have partial value, and this also serves as a reason for common injury in overwintering [37].

At the same time, plants can be subjected to the full passage of this or the other process in exactly controlled conditions (for example, in the station's artificial climate). For example, in I. I. Tumanov's recent experiments, apples were placed in frost at −60°, and blackcurrants even at −195°. The important task of studying in detail the system and potential possibilities of preparation for overwintering of all agriculturally important plants still faces plant physiologists.

However, knowing the conditions for the plants' acquisition of high winter resistance does not mean being able to manage them; and this is all the more true because the transfer of plants to conditions of rest and the acquisition by them of hardening in the usual case depends on intricate factors which we can't manage (length of day, temperature). However, tempting prospects are also open in this area for plant physiologists and agronomists.

The basis of any process of activity, such as the assimilation of elements of nutrition, growth and development, contain many strongly individual processes of the biochemical conversion of substances, energy, formation and changes of the structure and physical-chemical conditions of substances which agree among themselves.

All of these changes are regulated by the many biocatalysts, substances with high biological activity and specificity (enzymes, hormones, and vitamins) which are themselves products of the metabolism of substances.

Many of these substances have been studied, isolated, or synthesized artificially and are widely used in practice, as, for example, vitamins, the chemical regulators of the growth processes [38-44].

The natural or synthetic preparations are widely applied as stimulants for rooting, growth of fruits, or the plants themselves, for help in crossing genetically remote varieties of plants, for retarding the sprouting of potato tubers on continued shortage, for the elimination of weeds, etc. Several of these (gibberellins) show a specific effect on the growth of stems and the flowering of long-day plants [45].

Explaining the mechanisms of the action of chemical preparations in the plant and making apparent the relationship of the physiological activity of the preparations to their structure and physical-chemical properties must have an important place in further investigations on the development of a system using chemical preparations.

This makes possible the use of chemical and physical agents for management by the different systems of the metabolism of substances lying at the base of the physiological functions of the growing organism and probably deeply interfering with the path of the various physiological processes and conditions, including resistance.

Thus, one will be able, by rationally combining artificial influences of active biocatalysts with technical agriculture methods, to accelerate, strengthen, and induce processes in the desired direction affecting the processes of growth and development, the path of change in age conditions, and the development of resistance to unfavorable factors, and to create still unseen possibilities for management by the formation of yields which will be several times as large as at the present time.

The above does not exhaust by far all of the great questions that must be resolved by plant physiologists in the interests of increasing the yield of plants. However, enough progress has been made to see that plant physiologists have already given and are giving many practical means directed at increasing the productivity of agriculture while penetrating ever deeper and deeper into the very nature of the physiological processes, and finding ever newer and newer means and possibilities for the effective and strongly directed influencing of plants; in addition to this, plant physiologists are rapidly approaching the time when the accumulated knowledge can serve as a basis for a new qualitative jump in the progress of agriculture, a jump no less great and significant than that which was generated by the development of the bases of mineral nutrition of plants established in the nineteenth century by the works of plant physiologists and agricultural chemists.

The accumulated results of investigations and the strongly growing technical possibilities of the works of physiologists already suggest this in view of the new and extraordinarily effective methods as, for example, the use of artificial climate, the method of trace atoms, and other modern means, such as the achievements of physicists and chemists, which are being used more and more as active participants of biologists and, in particular, plant physiologists, in the development of important biological problems.

Plant physiologists must use these possibilities in the tasks and goals before them, and must be active participants in resolving the great tasks put before our country by the XXI Congress of the Communist Party of the Soviet Union.

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PHYSIOLOGICAL FEATURES OF THE CULTIVATION OF HARD SUMMER WHEAT IN THE CONDITIONS OF THE STALINGRAD REGION

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Hard summer wheat is the most valuable among cultivated grain crops according to its technological qualities, high protein content and transparency.

The main region for the cultivation of the hard wheat is the southeastern part of European USSR, including the Stalingrad region.

The climatic conditions of the Stalingrad region are characteristically inadequate, often with a complete absence of precipitation in the summer period and commonly occuring long droughts. These conditions, while accounting for the deep occurence of ground water, also cause strong atmospheric and soil drying. All together, this emphasizes the importanct of moisture, a basic limiting factor in obtaining large harvests in the semiarid steppes of the Stalingrad region.

It is very important in these given conditions to study and explain the physiological features of hard summer wheat in relation to technical agriculture and other factors formed upon the cultivation of this crop in production. Also of no less importance is a study of hard wheat in comparison to the soft wheat in comparable conditions, keeping in mind the fact that the soft summer wheat is usually more productive than the hard wheat in the Stalingrad region.

A laboratory field experiment was established in 1956 on an area of black fallow for a comparative study of the hard and soft summer wheat, [1]. The final rain (April 20) and cultivation (April 26) took place prior to planting. Planting of the plots was done on April 28 and 29 by hand with a planting board at the rate of 270 seeds per square meter. The highly resistant regional varieties of Melyanopus 69 for hard wheat and Al'bidum C-43 for soft wheat were used for planting.

The planting was done on plots, 4 meters square, with six repetitions. The appearance of sprouts was noted on May 7 and 8.

Observations were made during the vegetation period on the path of the growth of the plants and the concentration of carbon [3] in the wheat leaves (Table 1).

We can see from the data given in Table 1 that the hard wheat is more leafy than the soft wheat. This excludes the observation made on June 12 when a higher weight and leaf area was noted for the soft wheat. The higher concentration of carbon in the hard wheat on all observation dates suggests a higher level of photosynthesis in these plants.

The higher intensity of the life processes of the hard wheat as compared with the soft wheat is also suggested by observations on the conditions of the plants at the time of the onset of the warm weather, starting June 4, 1956, and during the following days when the air temperature sharply increased from 14-16° up to 28-30°.

The observations carried out in this period showed that the intensity of transpiration of the hard wheat leaves was lower than for the soft wheat leaves (Table 2).

TABLE 1

The Dynamics of the Growth of the Assimilation Apparatus and the Concentration of Carbon in the Leaves of Hard and Soft Wheat

Indicators, per 100 plants	May 16	May 31	June 12	June 28
Hard wheat				
Number of living leaves	200	1010	1181	500
Dry wt. of living leaves, in g	11.0	113.1	134.2	80.6
Area of leaves, in cm^2	1082	8087	9594	120
Conc. of carbon in the leaves, as % of dry substance	44.50	37.13	41.07	43.16
Soft wheat				
Number of living leaves	211	820	1140	300
Dry weight of living leaves, in g	9.3	62.7	144.9	19.8
Area of the leaves, in cm^2	690	4783	11 054	68
Conc. of carbon in the leaves, as % of dry substance	42.30	36.45	38.83	41.74

TABLE 2

The Intensity of Transpiration (in g of water per hour per square meter of leaf area)

Wheat	June 5		June 15	June 28
	at 1100 hr	at 1500 hr		
Hard	190.03	332.16	574.62	249.78
Soft	313.00	513.73	683.53	101.49

The intensity of transpiration of the hard wheat exceeded that of the soft wheat only toward the end of the period of milk ripeness (June 28).

These data suggest the higher drought resistance of the hard wheat, and this is supported by the higher water-holding ability of the leaves of hard wheat with a similar concentration of water in them. Thus, on May 31 the leaves of hard wheat lost water (as a % of the dry weight of the leaves) to the extent of 6.45% when held in the exsiccator above a solution of strong sulfuric acid (in the ratio, 1:1) and exposed for a period of two hours; but the leaves of the soft wheat under these same conditions lost 8.22%; on June 1 with the same exposure, the losses were 4.07% and 7.87%, respectively; on June 12, with exposure for 3 hours, 17.32% and 23.71%; on June 28, with exposure for 3.5 hours, 5.49% and 10.28%. Thus, the water-holding ability of the leaves of hard wheat was higher than the water-holding ability of the leaves of soft wheat in all data of the observations.

An important factor in obtaining a high yield is the character of development and distribution of the root system [2-7]. In our experiments, the average number of secondary roots on one plant of hard wheat was 4.43, and on the soft wheat, 5.41. The weight of the roots per square meter of planting in the soil layer from 0-40 cm was 51.1 g for hard wheat and 38.5 g for soft wheat. The distribution of the roots by weight (in %) by soil horizons showed the following for hard and soft wheat: in the layer from 0-10 cm, it was 74.3% for hard wheat and 84.1% for soft wheat; in the layer from 10-27 cm, 20.0% and 8.9%, respectively; and in the layer from 27-40 cm, 5.6% and 6.9%. The area of effective absorbing surface of the roots per square meter of planting in the soil layer from 0-40 cm was 3.19 square meters for hard wheat and 3.37 square meters for soft wheat. The distribution of the roots by area of effective absorbing surface of the root system for hard and soft wheat was also different, as follows: in the soil layer from 0-10 cm, 63% of the roots of hard wheat appeared, but only 58.8% of the roots of soft wheat; in the layer from 10-27 cm, 27.9% and 24.2% respectively; and in the layer from 27-40 cm, 9.1% and 17.0%.

We can see from the given data that hard wheat develops fewer secondary roots than soft wheat. Its somewhat smaller effective absorbing surface of the roots is destributed largely in the depth from 0-27 cm, and in the soil horizon from 27-40 cm is only 9.1%, while 17.0% of the effective abosrbing surface of the roots for the soft

TABLE 3

The Dynamics of the Increase of Assimilating Apparatus and the Concentration of Carbon in the Leaves of Hard Wheat in Relation to the Means of Basic Soil Treatment

Indicator	1955 (on waste land)				1956 (on fallow)			
	May 6	June 7	June 20	July 5	May 26	June 7	June 19	July 3
1. Tilled with a plow with preplowing to a depth of 25-27 cm plus soil depression of 10 – 15 cm								
Number of living leaves per 100 plants	900	1590	627	158	631	2080	2750	1570
Area of leaves from 100 plants (cm^{-2})	6827	21 832	2285	1967	3455	20 376	19 707	5313
Area of 100 leaves (cm^{-2})	759	1373	1481	1245	548	980	717	338
Concentration of carbon in the leaves (as % of dry weight)	39.38	39.68	40.80	40.43	39.15	41.50	43.80	43.35
2. Cultivated with plows without moldboards to a depth of 35 – 40 cm								
Number of living leaves per 100 plants	733	1481	747	188	725	1980	2010	1570
Area of leaves from 100 plants (cm^{-2})	5600	15 278	9001	1938	4152	21 894	13 744	6936
Area of 100 leaves (cm^{-2})	764	1032	1205	1028	573	1106	684	442
Concentration of carbon in the leaves (as % of dry weight)	39,80	39,68	39,98	39,60	39.60	43.20	44,50	43,95
3. Disced to 5 – 7 cm								
Number of living leaves per 100 plants	660	1478	435	0	—	—	—	—
Area of leaves from 100 plants (cm^{-2})	3600	12 085	2524	0	—	—	—	—
Area of 100 leaves	545	818	580	0	—	—	—	—
Concentration of carbon in the leaves (as % of dry weight)	39,80	39,68	40,65	0	—	—	—	—

TABLE 4

The Weight of Dried Leaves (as % of the dry weight of all leaves)

Experimental variant	1955 on wasteland		1956 (on fallow)	
	June 20	July 5	June 19	July 3
Plowed	33.1	64.8	9.5	47.0
Cultivated	21.4	52.8	9.2	19.1
Disced	33.7	100.0	—	—

TABLE 5

The Average Daily Growth of Plants by Periods (in g dry weight per 100 plants)

Experimental variant	1955 (on wasteland)			1956 (on fallow)		
	Sprouting to May 20	May 21 to June 7	June 8 to July 5	Sprouting to May 26	May 27 to June 7	June 8 to July 3
Plowed	1.25	8.07	6.23	0.58	6.65	7.79
Cultivated	1.07	6.01	6.77	0.70	7.15	8.62
Disced	0.77	5.23	0.88	—	—	—

TABLE 6

The Distribution of the Root System of Hard Wheat by Soil Horizons (in %)

Experimental variant	1955 (on wasteland)			1956 (on fallow)		
	0–10 cm	10–27 cm	27–40 cm	0–10 cm	10–27 cm	27–40 cm
By weight of roots						
Plowed	49.8	33.1	17.1	56.1	23.1	20.8
Cultivated	35.0	39.3	24.7	26.2	52.0	21.8
Disced	52.7	22.5	24.8	—	—	—
By are of effective absorbing surface of the roots						
Plowed	30.7	34.9	34.4	31.9	35.8	32.3
Cultivated	26.4	43.8	29.7	27.8	33.5	38.7
Disced	43.5	27.5	29.0	—	—	—

TABLE 7

Reserves of Available Moisture in a One Half Meter Layer of Soil (in cubic meters/hectare)

Experimental variant	1955 (on wasteland)				1956 (on fallow)			
	June 13	May 17	June 15	July 29	May 9	June 9	June 28	July 16
Plowed	1138	950	595	160	1056	302	132	0
Cultivated	1349	870	776	189	1133	356	83	32
Disced	763	464	297	0	—	—	—	—

TABLE 8

Intensity of Transpiration of Hard Wheat (in g of water per hour per square meter of leaf area)

Experimental variant	1955 (on wasteland)				1956 (on fallow)				
	May 21	June 8	June 21	July 5	June 7		June 19		July 3
	In the daylight hr (1200–1400)				1100 1200	1500 1600	1100 1200	1500 1600	1500 1600
Plowed	72.11	378.35	204.2	147.4	211.93	349.47	220.42	63.2	167.52
Cultivated	470.05	346.8	262.4	196.0	239.75	384.35	130.08	46.54	134.81
Disced	276.51	562.11	211.5	0	—	—	—	—	—

TABLE 9

The Yield of Wheat and Average Daily Consumption of Water by the Plants

Experimental variant	Yield of grain in centners per hectare		Average daily consumption of water by plants (mm per ha)	
	1955 (on waste-land)	1956 (on fallow)	1955	1956
Plowed	12.33	8.88	2.73	3.13
Cultivated	13.35	9.85	2.45	2.77
Disced	5.70	—	1.53	—

wheat are located in this soil layer at the same time. This is very important because the reserves of available moisture in the upper horizon of the soil toward the end of the period of milk ripeness have been completely exhausted, as we can see from the following data (in mm).

	0-020 cm	0-50 cm	0-100 cm
May 8	42.7	90.7	119.0
June 7	16.8	48.9	79.3
June 28	0.9	4.0	11.2

In spite of the unfavorable distribution of the root system by soil horizon, hard wheat gave a higher yield of above-ground mass than the soft wheat (1025 g as against 563 g for the soft). This contradictory fact apparently can be explained by the different physiological activity of the roots for hard and soft summer wheat that is supported, to a certain degree, by the data on the weight of the above-ground mass for every square meter of effective absorbing surface of the roots (321 g for hard wheat against 167 g for soft wheat). At the same time it is necessary to note that the hard wheat is more economical in the use of soil moisture than the soft wheat. Thus, the transpiration coefficient for the first is 420.7 and for the second, 557.8.

In 1956 in a number of areas in the Stalingrad region, a mass condition of barren spikes in hard wheat was observed on significant areas (100-200 hectares) on five collective farms in the Frolovsk and Frunzensk regions. The condition of barren spikes was not observed for plantings of summer wheat grown under similar circumstances. Observations showed that there was a sharp deterioration in the meterorological conditions accompanied by a decrease to zero of the available moisture reserves in the upper horizon (0-50 cm) at the end of May and beginning of June (during the phase of branching and the emergence of the flower).

We can see from the comparison of the data on the reserves of available moisture in the soil with the data of the development and distribution of the root system that the basic reason for the barren spikes of hard wheat as compared to the soft wheat is an inadequate depth of penetration of the roots into the soil, as a result of which the plants could not use the moisture available in the deeper soil horizons [1].

Deep treatment of the soil can aid both in the accumulation of large reserves of moisture in the autumn-winter period and in the more favorable distribution of the root system of hard wheat in the soil layers.

In the favorable year of 1955 the physiological features of hard wheat, variety Melyanopus 69, were studied on the Stalingrad Agricultural Experimental Station in relation to the means of basic treatment of old wasteland [8-11]. A similar study was carried out in the dry year of 1956 with planting of wheat on fallow.

The observations made during the vegetation period in 1955 and 1956 showed significant differences in the path of the growth of the plants in relation to the means of basic treatment of the soil.

The path of the increase of the assimilating apparatus of plants and the intensity of photosynthesis in relation to the means of basic treatment of the soil can be judged by the data given in Table 3.

We can see from the data given in Table 3 that smaller normal area of leaves per 100 plants is formed when wheat is planted on wasteland (1955) with the ground cultivated, and the leaves themselves are smaller than when the ground is plowed. A strong suppression of the plants already appears with the first observation (May 20) with a background of discing wasteland; there are no remaining living leaves in the phase of milk ripeness (July 5) and all leaves are dry, although the grain has not yet ripened.

Larger leaves are formed when planting takes place on a fallow (1956) with the ground cultivated, and the area of the leaves from 100 plants is also larger than with plowed ground (excluding the observation on June 19).

The concentration of carbon in the leaves, which characterizes the intensity of photosynthesis, is similar for all three of the treatment variants when the wheat is planted on wasteland (1955). When planting takes place on fallow, the concentration of carbon is higher on a background of cultivation.

The high survival of plants grown on cultivated ground can also be judged by the path of the drying of the leaves (Table 4).

A more nearly equal drying of the leaves was observed in the favorable year of 1955 than in the dry year of 1956. In both cases the drying of the leaves on the cultivated ground proceeded more slowly than on the plowed ground.

The higher survival of leaves of the plants grown on the cultivated ground is reflected in the average daily growth of the plants (Table 5).

The higher intensity of growth for plants on the cultivated areas is connected apparently with the character of the distribution of the root system in the soil (Table 6). The condition of the root system was determined after the formation of spikes when the growth of the roots has ceased in wheat [6].

We can see from the data in Table 6 that the main mass of the roots by weight, in which the large roots predominate, is located in the plowed ground in the horizon 0-10 cm (49.8% in 1955 and 56.1% in 1956), and in the cultivated ground in the horizon 10-27 cm (39.3% in 1955 and 52.0% in 1956). The main mass of the roots on the disced area is located in the horizon 0-10 cm (52.7%).

The data of the distribution of the effective absorbing surface of the roots merit the most attention. The effective absorbing surface of the roots is distributed in an equal manner by horizons for wheat planted on the old wasteland (1955) on the plowed area. On the cultivated area, the main part is located in the horizon 10-27 cm (43.8%).

The distribution of the effective absorbing surface of the roots by horizons when the wheat was planted on fallow (1956) was even more favorable on the cultivated area. The effective surface of the roots in this case increased with depth (27.8%, 33.5%, 38.7%) and the distribution of roots by horizon was nearly equal on the plowed background, as in 1955 (on the wasteland). The main mass of the active absorbing surface of the roots (43.5%) on the disced wasteland is located in the uppermost horizon (0-10 cm).

The distribution of the effective absorbing surface of the roots has significant importance for the growth of the plants because the reserves of available moisture in the upper horizons of the soil in the second half of the vegetative period of plants is significantly or completely absent (Table 7).

The data in Table 7 indicate that both on old wasteland and on the fallow, cultivation of the soil with nonmoldboard plows aids in the accumulation of large reserves of moisture [12, 13].

The data of the intensity of transpiration of the plants (Table 8) are also suggestive of the physiological features of plants in relation to the means of basic treatment.

The data in Table 8 suggest the great plasticity of plants grown on the deeply cultivated ground. Thus, the intensity of transpiration in the wet year of 1955 on the old wasteland was higher on the cultivated ground than on the plowed ground.

In 1956 in the first observation (June 7), when there was still sufficient moisture in the soil, the intensity of transpiration on the cultivated ground was higher than on the plowed ground; after this, the intensity of transpiration sharply decreased and this is connected, it appears, with the change-over in the growing organism itself.

The high intensity of transpiration on the disced ground, noted on June 8, 1955 (562.11 g), is connected with the surface distribution of the roots using, to a maximum degree, the precipitation which fell prior to this on June 3 to 6 in the quantity of 46.8 mm.

The path of the physiological processes for plants described above, the character of the distribution of the root system in the soil and the data on the reserves of available moisture in the one half meter layer were reflected in the productivity of the plants and the consumption of moisture (Table 9).

The data in Table 9 show a higher yield of grain (8.3% and 13.5%) and a more economical average daily consumption of moisture (11.4% and 11.5%) both in the favorable year of 1955 on the old wasteland and in the dry year of 1956 on the fallow against a background of deep cultivation with plows without moldboards, than on the ground plowed with moldboards.

The insignificant average daily consumption of water observed for wheat on the disced beds is accompanied by a relatively low yield of grain in view of the strong suppression of the plants.

SUMMARY

1. In the conditions of the Stalingrad region, hard summer wheat Malyanopus 69 possesses a higher degree of drought resistance than soft summer wheat Al'bidum 43. The hard wheat exhibits a high water-holding ability in the leaves, a lower intensity of transpiration and a better resistance to high temperatures; it possesses a higher potential for obtaining high yields according to the indicators of the intensity of photosynthesis, the structure of the harvest, and the more economical use of soil moisture.

At the same time, Melyanopus 69 has a more weakly developed root system and a poorer distribution of the root system in the soil horizons than soft wheat, a fact that reduces sharply the resistance of the plants in the severe, semiarid conditions of the Stalingrad region.

2. The character of the development of the root system, an insufficiently deep penetration of the roots into the soil under conditions of sharply decreased reserves of available moisture, is a basic reason for barren spikes in hard wheat.

3. According to the data of the two years, basic treatment of the soil by means of plowing without moldboards to a depth of 35- 40 cm, as suggested by T. S. Mal'tsev, shows better results for growing hard summer wheat in the conditions of the Stalingrad region than basic treatment of the soil by plowing with moldboards to a depth of 25-27 cm with soil depressions to 10-15 cm.

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CHROMATOGRAPHIC ANALYSIS OF SUGARS AND FREE AMINO ACIDS IN THE SAP OF GRAPE VINES

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The composition of substances moving in an upward direction in the grapevine has been inadequately studied up to the present time. Investigations were made primarily to describe the chemical composition of the grape and other organs of the grape vine. However these investigations did not make it possible to obtain a complete idea of the character of the rising flow of organic substances in the grape vine [1]. It is necessary to analyze the sap in order to explain this question.

According to the data of Merzhanian [2], the sap of the grape vine represents almost pure water. Its specific weight is 1.0007. There are 1 to 2 g of dry substance, of which $\frac{2}{3}$ is organic and $\frac{1}{3}$ mineral substance, for one liter of liquid. Almost analogous data are given in the French manual on viticulture [3]. Manzoni also shows that the consumption of substances is not large on bleeding of the grape vine.

The goal of the given work was the study of the basic forms of organic substances moving in an upward direction in the grape vine.

Analysis of the carbohydrates and free amino acids of the sap was carried out. The investigations were made throughout 1956 and 1957.

METHODS

In order to get an idea of the upward flow of substances, we studied the composition of sap that was obtained on exudation by the grape vine. A one-year-old ripe shoot was cut not far from its base for a sample of the sap. A rubber tube was attached to the cut and connected by means of a glass tube and a rubber tube with a test tube for sap collection. All of this system was thoroughly sterilized and the cut was treated with toluene with chloroform. Besides this, a small quantity of toluene and chloroform was left on the day of collection so that the end of the glass tube through which the sap flows was lower than the level of antiseptic liquid.

Our investigations showed that the composition of the sap changes significantly with the appearance of leaves and young shoots. Therefore the leaves and young shoots were constantly removed.

The liquid collected was concentrated 50 times under vacuum after which it was examined according to the accepted method of paper chromatography [5, 6].

According to our previous observations, the most applicable method for the study of the dynamics of soluble carbohydrates appears to be that of Matthias [7].

A mixture consisting of n-butanol, acetic acid and water in the proportions 4:1:1 was used for chromatographic analysis of the amino acids, and an 0.2% solution of ninhydrin in absolute acetone was used as the developer. A mixture composed of n-butanol, benzol, pyridine and water in the proportions 5:1:3:3 was used as the solvent in chromatographic examination of the carbohydrates. The chromatograms were developed with anilinephthalate. For its preparation, 1.66 g of phthalic acid and 0.93 g of aniline were dissolved in 100 ml of water saturated with butanol. For chromatographic paper, Schleicher and Schul No. 2043 B and No. 2043 A were used in the work.

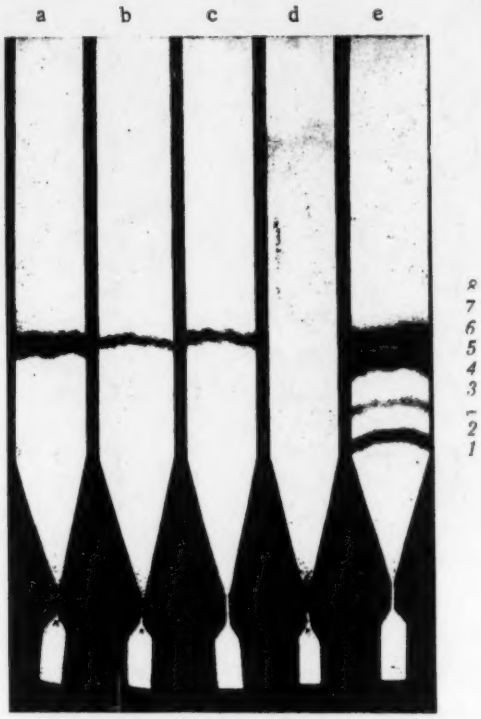

Fig. 1. Chromatograms of carbohydrates in the sap of grape vines. a, b, c) Sample of sap obtained on April 10, 1957; d) sample of sap obtained on June 27, 1957; a) variety Gymsa, not grafted; b) variety Gymsa grafted on wilding Monticola; c) wilding Monticola; e) standards: 1) raffinose; 2) lactose; 3) maltose; 4) sucrose; 5) galactose; 6) glucose; 7) fructose; 8) xylose.

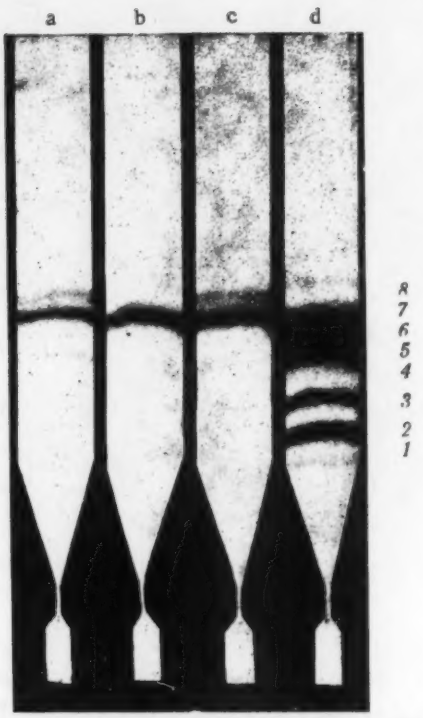

Fig. 2. Chromatograms of carbohydrates in the sap of grape vines. a) Variety Monticola, sap collection from a root cut; b) variety Monticola, sap collection from a shoot cut; c) variety Gymsa grafted, sap collection from a root cut. Standards: 1) raffinose; 2) lactose; 3) maltose; 4) sucrose; 5) galactose; 6) glucose; 7) fructose; 8) xylose.

We investigated the seasonal and daily changes in the concentration of sugars and amino acids in the sap of the grape vine. Variety Gymsa grown without grafting and with grafting on the wilding variety Monticola were used for the work. The sap of the wild vine of Monticola was analyzed as a control.

1. Changes in the Concentration of Sugars and Free Amino Acids in the Sap of Grape Vines at Various Stages of Vegetation

Significant changes in the concentration of carbohydrates and amino acids in the sap of grape vines take place over the duration of the vegetative period. Thus, glucose and fructose were invariably observed in the sap at the beginning of sap movement prior to the beginning of flowering (Fig 1). Glucose significantly predominated in the quantitative relationship. The concentration of sugars in the sap began to decrease beginning with the moment of flowering, and they had completely disappeared from the sap toward the end of flowering. This shows that the root system of the grape vine, along with its other functions, fulfills the role of a reserve organ and continues to pass nutrient substances to the aerial portions of the plant up to the period of flowering. This has already been shown earlier by one of us [8]. After the flowering period the assimilates formed in the process of photosynthesis completely satisfy the demands of the plant for nutrient substances necessary for its growth and fruiting. At this time part of the assimilates move to storage in the older parts of the plant and in the root system.

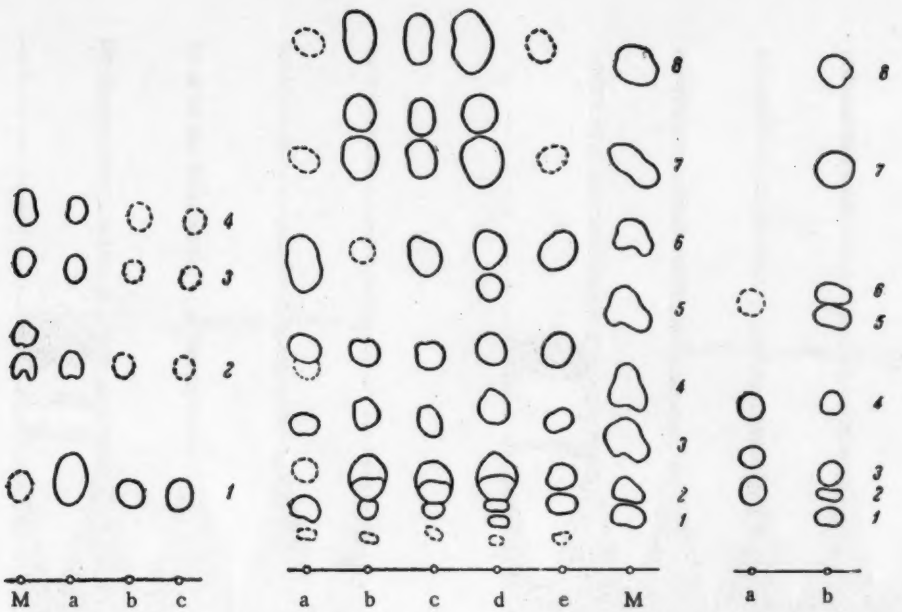

Fig. 3 Fig. 4 Fig. 5

Fig. 3. Chromatograms of amino acids in sap collected on March 20, 1957. a) Wilding, variety Monticola; b) variety Gymsa, not grafted; c) variety Gymsa, grafted; M) standards: 1) aspartic acid; 2) glutamic acid; 3) valine; 4) isoleucine.

Fig. 4. Chromatograms of amino acids in sap collected on May 14, 1957. a) Variety Gymsa, not grafted; b) wilding, variety Monticola, sap collected from root cut; c) wilding, variety Monticola, sap collected from shoot cut; d) variety Gymsa, grafted, sap collected from root cut; e) variety Gymsa, grafted, sap taken from shoot cut.

Fig. 5. Chromatograms of amino acids in sap collected on July 5, 1957. a) Variety Gymsa, not grafted; b) standards: 1) cystine; 2) lysine; 3) aspartic acid; 4) glutamic acid; 5) alanine; 6) proline; 7) valine; 8) leucine.

We observed that sucrose is also present, in addition to fructose and glucose, in the sap when it is gathered directly from the cut roots. Only fructose and glucose are observed in the sap from one-year-old cut shoots, as already noted above (Fig 2). It was established through further, more detailed, investigations carried out with many varieties (gymsa, Zarchin, and others) that there is also sucrose in the sap flowing from cuts on the aerial portions of the plant; however, it is found in such minute quantities that, in order to observe it on chromatograms, a preliminary concentration of the sap or not less than 100 times is needed. A decrease in the concentration of sucrose in the sap when the sap passes through the stem is possibly explained by its partial hydrolysis.

Changes in the amino acid composition of the sap are shown on chromatograms 3, 4 and 5. We analyzed the amino acids of the sap on five dates: March 20, April 10, May 14, June 5, and July 5. The data obtained showed that a limited number of amino acids are held in the sap of the grape vine variety Gymsa, grown without grafting and also in the sap of the wilding Monticola; aspartic and glutamic acids, valine and isoleucine. The number of amino acids in the sample of sap increased on the following dates. Nine amino acids were observed in the sap on April 10. Lysine, alanine, pyrosine, phenylalanine, and one substance which we did not identify, appeared in the sap. On the third date a still larger increase in the amino acids in the sap was observed. In addition to those listed above, histidine, cystine, and also several unidentified substances were observed. The most amino acids were observed in the sap flowing from the cut on the Monticola wilding.

Fig. 6. Chromatograms of carbohydrates in the sap of grafted grape vine variety Zarchin. (Sap collected on May 30-31, 1957). a) Sample of sap from 8 A.M. to 2 P.M.; sample of sap from 8 P.M. to 8 A.M.; standards: 1) raffinose; 2) lactose; 3) maltose; 4) sucrose; 5) galactose; 6) glucose; 7) fructose; 8) xylose.

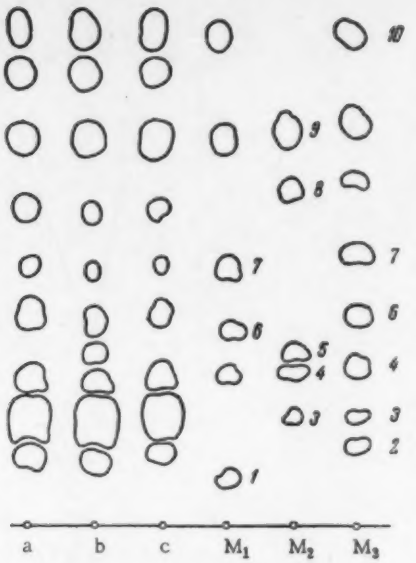

Fig. 7. Chromatograms of amino acids in the sap of nongrafted grape vine, variety Gymsa. (The sap was collected on May 30 to 31, 1957) a) sap collected from 8 A.M. to 2 P.M.; b) sap collected from 2 P.M. to 8 P.M. c) sap collected from 8 P.M. to 7 A.M. M_1, M_2, M_3) Standards: 1) cystine; 2) cysteine; 3) lysine; 4) aspartic acid; 5) arginine; 6) glutamic acid; 7) alanine; 8) tyrosine; 9) valine; 10) isoleucine.

A decreased collection of amino acids was noted in the sap obtained at the beginning of flowering (June 5). Their number decreased to 7-9. Cystine and tyrosine disappeared on this date; however proline and alanine appeared. The collection of amino acids in the sap decreased even more toward the end of June and beginning of July. On July 5 the presence of only four amino acids was established in the sap of the nongrafted variety Gymsa: lysine, aspartic acid, glutamic acid, and proline. We failed to gather a quantity of sap sufficient for chromatographic analysis for other varieties on this date.

Thus it was established in our experiments that the composition of the amino acids passing from the roots into the shoots changes significantly during the vegetative period. This makes it possible to suppose changes in the synthesizing activity of the roots.

The synthesizing process in the roots leading to the assimilation of mineral nitrogen was studied in detail by Kursanov [9, 10, 11] and Potapov [12, 13]. Investigation on the formation of nicotine also indicated the synthesizing function of the root [14-19]. All of these processes take place in the roots on the basis of the carbohydrates flowing from the shoots. However, as we have shown [8], there was no movement of carbohydrates observed from the aerial to the below-ground parts up to the period of flowering in the grape vine. Consequently, the absorption and treatment of nitrogen in the roots proceeds at this time in proportion to the carbohydrates put aside earlier in the reserves.

Two more rules must be noted in continuing the examination of the data which we obtained. The first of these is included in the fact that the substances formed in the roots proceed through the joint of the graft of the grape vine without change. This is indicated by the absence of differences in the amino acid and

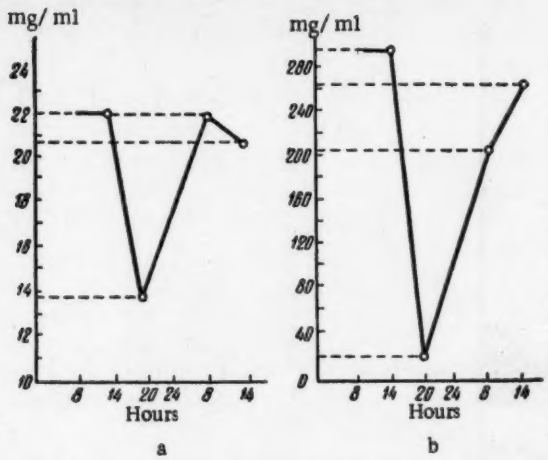

Fig. 8. The diurnal dynamics of the concentration of sugars and amino nitrogen in the sap of grape vines, variety Zarchin (grafted). Sap collected on April 22-23, 1957. a) Sugar; b) amino nitrogen.

carbohydrate composition of the grafted and the nongrafted plants. The second feature in the upward movement of sugars and amino acids in the grape vine consists of the fact that collections were similar for all of the varieties that we studied. Even varieties separated by their geographical range and biological features (Pamid, Cherven muscat, Shasla X., Berlandieri 41b, Zarchin, Vitis Berlandieri, and others) did not have any differences in the number of amino acids and sugars in the sap. Thus, the carbohydrates in the sap of all of the varieties that we examined were sucrose, glucose, and fructose. This shows that the movement of carbohydrates from the root system to the aerial parts is accomplished just by these three sugars. However, the main transporting role, in all probability, is fulfilled by glucose, which is held in the sap in a significantly greater quantity than fructose and sucrose. While the number of amino acids in the sap of grape vines is usually very large, apparently aspartic acid, glutamic acid, valine, isoleucine, and lycine are of main importance in the movement of organic nitrogen in an upward direction. These five amino acids were found in the sap throughout the vegetative period. Lysine, which was absent in the sap at the beginning of sap movement (March 20) is excluded.

All of this makes it possible to hypothesize that the movement of organic nitrogen from the root system of grape vines takes place largely in the form of the five amino acids listed above. However it must be acknowledged that histidine and asparagine have some role in the transportation of nitrogen. Here we must remember that a large variety of amino acids in the sap of different plants was already noted by Mothes and Wolffgang [21] and Reuter and Wolffgang [22].

2. Daily Changes in the Concentration of Sugars and Amino Acids in the Sap of Grape Vines

The fact that a definite rhythm was observed in the flow of sap for many plants was known long ago. According to several authors this rhythm originates in the process of phylogenetic and ontogenetic adaptation of plants to the diurnal changes in the conditions of the external environment [23]. According to other authors [24, 25], the rhythm in the flow of plants is connected with changes in the activity of respiration of the root system. Thus, Trubetskova [26] established the fact that plants which have a diurnal rhythm in flow exhibit also a diurnal rhythm in the respiration of the root system. On the other hand, plants for which no specific rhythm is observed in the sap flow during the different hours of the day also have no rhythm in the respiration of the roots. Recently Gunar and his colleagues [27] established changes in the intensity of the exuding of sap every 15 to 30 minutes. This gives a basis for concluding that there exists a pulsation in the activity of the root system. According to several authors, the pulsation is especially clearly expressed in those cases where the plant does not have a diurnal rhythm in sap flow.

While we were following the changes in the composition of sugars and amino acids in the sap of grape vines throughout the vegetation period, we attempted to find out if such changes exist in the period of a day. Appropriate chromatograms of the sugars and amino acids in the sap were obtained for this purpose. Besides this, quantitative determinations of the concentration of sugars and amino nitrogen in the sap were carried out.

Chromatograms of the sugars and amino acids are presented in Fig. 6 and 7. They show that differences in the quantitative composition of the sugars and amino acids are not observed at various times of the day; also, the number of amino acids and carbohydrates remains constant day and night. Fructose and glucose are found among the sugars in the upward movement, and cystine, lysine, histidine, aspartic and glutamic acids, alanine, tyrosine, valine, phenylalanine, isoleucine, and one unidentified substance are found among the amino acids.

However, quantitative analysis showed a diurnal rhythm in the concentration both of sugars and of amino nitrogen in the sap (Fig. 8). For this, the rhythm on the flow of sugars and amino nitrogen was similar. We see on the graphs in Fig. 8 that the maximum flow of the substances is reached from 8 A.M. to 2 P.M. After this period their quantity progressively decreased and was at its minimum at 8 P.M. The concentration of the sugars and amino nitrogen in the sap again increased at night and approached the maximum figure toward 8 A.M.

We must keep in mind the fact that, in contrast to us, Mokronosov and others [28] found diurnal changes in the qualitative composition of the amino acids in the sap of potato. They observed about 10 to 12 amino acids between 10 A.M. and 5 P.M. Later, between 5 P.M. and 10 P.M. the number of amino acids in the sap sharply dropped. Subsequently the decrease in the number of amino acids continued between 10 P.M. and 3 A.M. The authors connect these changes with the substantial periodicity of photosynthesis and the flow of assimilates toward the roots.

SUMMARY

1. The study of the upward flow of substances in grape vines showed that significant changes take place in the concentration of sugars and amino acids in the sap during the vegetation period.

2. Fructose, glucose and sucrose are found in the sap in the period of intensive sap movement. The concentration of carbohydrates significantly decreases toward the end of flowering, and the carbohydrates completely disappear from the sap after flowering.

3. Of all the forms of sugars in the sap, glucose significantly predominates. Apparently it fulfills an important transport role in the movement of carbohydrates from the root system to the aerial parts of the grape vine.

4. The carbohydrate composition of the sap from root cuts and cuts of one-year-old shoots was similar. However, there was less sucrose in the sap flowing from shoot cuts than in the sap from root cuts.

5. A significant number of amino acids that undergo important changes during the vegetation period were found in the sap of grape vines. At least four amino acids are found in the sap at the beginning of sap movement. Later the number of amino acids increased, approaching a maximum toward the middle of May (twelve amino acids). The number of amino acids in the sap drops at the time of flowering, and only four amino acids were again discovered at the beginning of July.

6. In all, the following amino acids were identified in the sap: aspartic acid, glutamic acid, valine, isoleucine, lysine, alanine, tyrosine, phenylalanine, cystine, histidine and proline. Aspartic and glutamic acids, valine, isoleucine, and lysine, which were found in the sap throughout the entire vegetation period, are of basic importance in the movement of organic nitrogen in an upward direction.

7. There were no variety differences observed in the composition of the sugars and amino acids of the sap.

8. The qualitative composition of substances did not change on their movement from the root system to the aerial organs. Also the qualitative composition did not change on movement of the substances through the graft.

9. The presence of changes in the compositions of the sugars and amino acids over the period of the day in the sap of grape vine was established. However, quantitatively they have a diurnal rhythm. It was largest during the day, approached a maximum in the period from 8 A.M. to 2 P.M., decreased in the following night hours, and again increased toward morning.

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PERIODIC VARIATIONS OF BIOELECTRIC POTENTIALS IN TRADESCANTIA

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The measurement of bioelectric potentials (BP) in plants can be made rapidly and during the entire span of development. Accordingly the BP method of measurement has a great advantage over the method of measuring extracts prepared from vegetable tissue. Moreover, the destroyed plant cells can hardly be expected to reproduce all the physiological processes which take place in a living organism. Therefore, measurements conducted on extracts prepared from vegetable cells may be questionable in some cases and the electromotive force (EMF) values obtained obviously refer to purely physicochemical processes occuring in these "pulps."

BP values can be of practical use not only experimentally, but also for control of the agricultural plants' life activity, and to determine the optimum doses of various stimulants.

One of the problems in our further investigations was the necessity of uninterrupted recording of plant BP over a period of days and months, in order to determine the course of variations in electrical activity of the plant organism over a prolonged period and in relation to changes in the external environment. We found Tradescantia zebrina to be the most suitable item for methodical investigation, as our preliminary observations have shown.

The study was conducted in the Tbilisi affiliate of the All-Union Scientific Research Institute of Electrified Agricultural Industry.

METHODS

The first experiments on round-the-clock measurements and recording of plant BP were started in May 1956 using a screened light chamber, platinum silver chloride electrodes, and equipment described in earlier studies [1,2].

The sensitivity of a cathode-ray oscillograph to slowly changing or constant potentials was 1 millivolt/mm, and 0.2 millivolt per scale division in recording on a paper tape by a self-recorder. Conversion frequency was 50 cpm, and the frequency characteristic of booster rectilinearly from 0 to 10 cpm.

Prolonged observations of BP were also conducted to learn the acclimatization process of platinum electrodes toward plant tissues, since to secure an uninterrupted recording of BP linked with reactions of external environments it becomes necessary to maintain a constant drain by electrodes of the potential difference (PD) without disturbing the platinum electrode's contact with plant cells.

Rubinshtein [3] objected to use of platinum electrodes for measuring plant BP; in investigating EMF of biological origin he suggested use of the principle of two markedly individual potential groups of an electronic and ionic type, considering that the electronic type consists of potentials for the formation of which donors as well as electron acceptors are necessary, i.e., any metallic galvanic chain, which becomes an oxidation-reduction chain. D. L. Rubinshtein places the potentials of the second group, possessing a purely ionic nature, in direct opposition to the electronic type, considering that only potentials of an ionic type can serve to explain bioelectrical phenomena — interphasal, membranous and diffusional.

However, it should be remembered that the biological oxidation-reduction reaction is due to enzyme activity capable of incorporating or liberating electrons in this process. The enzymes act as if they accomplish a role similar to a metal in galvanic oxidation-reduction reactions. Thus, the transfer and movement of electrons is biological oxidation and reduction is accomplished without any metal. Consequently, it is unreasonable to consider bioelectrical processes as having a purely ionic character.

In order to preclude gross destruction of plant cells when platinum electrodes are forced in, we also used liquid silver chloride electrodes and a 1% KCl solution, which allows removal of BP from vegetable tissue surface with minimum irritation.

The electrodes are braced by a clamping device to a hinge. The hinge consists of two metal globes connected by a porcelain cylinder approximately 15 mm long. As braced, the electrodes can move freely in all directions, while movement up and down and along a horizontal plane is accomplished by an arrangement of a bushing along a vertical rod. The necessary stability is accomplished by a screw.

In these experiments, obviously even a very small electrode removes the potential from the sector of tissue surface or the cell itself, where the composite mosaic of vast numbers of positively and negatively charged groups are distributed. Therefore an electrode will become an integrator of a charge of enormous numbers of points. Surfaces totally different in their properties as charge carriers can be obscured by determined equal values of a directly measured potential. However, an effect of one charged surface on another is not excluded, and the electrode on the whole will register general changes occurring in the system of living cells, and in the case of a microelectrode, in a single cell.

BP investigation has shown that in a number of cases quite divergent factors of damaging influences affect the precision of measurements, such as: a) mechanical irritation or injury of the plant cell; b) electric current caused by the measuring installation itself (polarization of cells, tissue and electrodes by the continuous current source); c) effect of external electromagnetic and electrical fields on the measured object. These last must be excluded by a screened light chamber [1,2].

External electromagnetic fields create an additional EMF in the measuring chain which adds to the EMF of plant tissue and is recorded by the measuring apparatus of the magneticelectrical system. The method applied in our investigation permitted graphical differentiation of plant BP from externally developed EMF by the use of a cathode-ray oscillograph.

As a control a simultaneous record was kept of line voltage feeding the measuring installation, the temperature of surrounding air by thermograph, the air humidity by a hygrograph, air pressure by a "Gidrometpribor" barograph. All the BP recordings were made at a rate of 120 mm/hour.

DIURNAL VARIATIONS OF BIOELECTRIC POTENTIALS

The considerable experimental material at our disposal has shown that the BP on individual sections of plant tissues of tradescantia, orange, lemon, and other plants are not a constant magnitude, but vary depending on the external environment and on many physical factors. Moreover, as is natural, BP varies in magnitude and in character periodically during the day. During spring, in the period of acceleration of life processes, an especially turbulent electrical activity, expressed in rhythmic vibrations, is noted.

An uninterrupted recording of Tradescantia zebrina BP was begun on May 5, 1956 and continued to December 11, i.e., it lasted almost 7½ months. Removal of PD was conducted from different platinum electrodes placed at the leaf formation along the stem axis. The first platinum electrodes were put into the plant stem on April 28, the other six pairs at monthly intervals. A characteristic regularity in the rise of electrical activity became apparent daily during the entire spring period, from approximately 11 A.M. to 1 P.M. (Fig. 1 b,c).

Similar measurements were conducted on kidney beans, lemon, and orange seedlings using platinum electrodes on different tissue sectors, but PD variations such as those found in tradescantia were not observed.

Subsequent tradescantia BP recordings showed that rhythmic PD variations begin at once after the electrodes are placed in the plant stem, but by July no such definite and periodic oscillations were noted as those observed in the previous recordings (Fig. 1 b and c). Moreover, the rhythmic PD oscillations attenuate much more rapidly over 3-4 hours and do not recur on new electrodes. During the entire month we found no steady rhythmic BP oscillations. Only beginning July 10 did they appear at a lower amplitude and continued up to July 15.

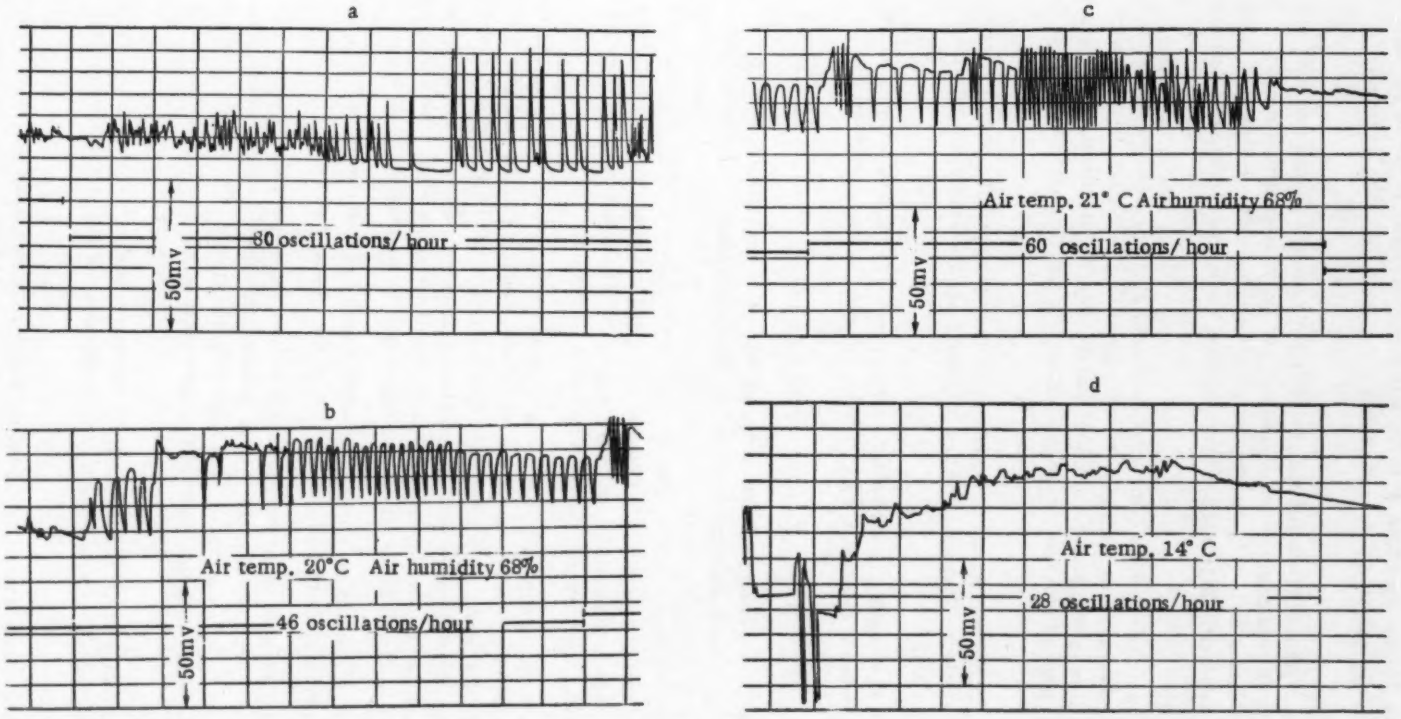

Fig. 1. Rhythmic oscillations of tradescantia bioelectric potential (BP): a) morning hours, the period from 11 A.M. to 12 A.M.; b, c) evening hours, the period from 8 to 9P.M.; d) rhythmic BP oscillations drained off by means of silver chloride electrodes in the autumn (on November 9 at 10 A.M.).

Subsequent daily recordings no longer reproduced the BP oscillating character. After this follows a linear recording with very rare splashes a few hours apart. This picture was observed up to November 29. On December 10 platinum electrodes were placed anew in tradescantia stems, as in the former experiments. Rhythmic PD oscillations appeared between electrodes on the same day only at 6 P.M.; but considerably smaller in form, frequency, and amplitude than in May.

On the following day the rhythm of PD oscillation gradually diminished, decreasing to zero, and appeared no more. As a comparison with PD measurements using platinum and liquid electrodes, there is special interest in a BP recording (Fig. 1 d) conducted at 10 A.M. on November 9 using silver chloride electrodes coming in contact with tradescantia leaf tip and stem. In recordings made over the entire day PD rhythmic variations were observed only at 1 P.M.

Careful control of the external environment and a comparison of different parameters of external factors such as, for example, the temperature, humidity, air pressure, external electromagnetic and electrical fields, etc., with measured BP levels afforded the basis for asserting that the observed electrical activity expresses physiological and biochemical internal processes in the plant tissue, and not physical phenomena in the measuring chain of apparatus.

We regret that we were unable to maintain a constant control of the respiration process and photosynthesis in the whole period of BP observations. Therefore, we can only make certain assumptions regarding the cause of BP oscillations, based on facts noted.

Rhythmic BP oscillations in tradescantia were observed in removal by means of platinum electrodes as well as in removal by liquid silver chloride electrodes, cell irritation and destruction notwithstanding.

DISCUSSION OF RESULTS

Considerably later, after having completed this study, we learned of the existence of rhythmic potential oscillations also in roots of kidney beans sprouting in water [4]. In another study [5] rhythmic oscillations in the electrical field stimulated by Vicia faba roots in an aqueous 0.0001 N KCl solution were investigated. The recording was made in 5 seconds by an automatic recorder with a maximum sensitivity of 1 millivolt over the entire width of paper tape, by dots of different colors corresponding to the 6 channels. The recording speed was 120 mm per hour, the same speed as in our study. A bulb electrometer at the self-recorder inlet provided great inlet resistance of the apparatus. Two calomel elements served as electrodes.

The electrical field's maximum amplitude was located within 8 mm from the root's tip and attained 5 millivolts, and the average cycle was 5 per minute. The amplitude magnitude slowly rose to a maximum, and then slowly fell with the cycle for nearly 2 hours and coincided with the cycle of root-growth movements. The author in question [5] considers the rhythmic process of the electric field oscillation around the sprouting root as a complex closed system with a negative bond, widely prevalent in technology and in living systems, with the capacity of stabilizing the direction of the system and adjusting it to the external environment.

Evidently, the complex of processes comprising a reversible bond in plants cannot be only an electrical one, but this bond, in all probability, eliminates the necessity of the existence of a nervous system.

Rhythmic PD variations also occur in myxomycetes plasmodium (Physarum palycephalum) with a cycle of 3-5 per minute and an amplitude up to 4-10 mv [8]. In addition, this phenomenon has been found also in a unicellular parasitic infusarium (Opalina ranarum) using glass microelectrodes [7]. Against a background of slow periodic PD oscillations faster oscillations exist lasting from portions of a second up to 2-3 seconds and with an amplitude of 1-3 mv.

A comparison of PD recording curves found by other authors [5,8] with ours (Fig. 1 b and 1 c) shows some similarity in oscillation form, but the amplitude magnitude in tradescantia and in Vicia faba is somewhat greater than in the unicellular forms.

Even in some physicochemical systems during the oxidation-reduction reactions [9] rhythmic PD variations were found, with an amplitude of hundredths of a millivolt and a cycle of 5-6 up to 16 per second. This phenomenon is explained by the different rates of the oxidation-reduction reactions's course on the electrodes.

Rhythmic BP variations are observed in the animal organism as well as in plants, and are closely connected with the stimulatory process [3, 10-15]. The possibility is not eliminated of the existence of BP rhythmic oscillations in plants even of the order of magnitude of microvolts. Incomplete reports on this problem are published in the literature [2], and the oscillating character of electric potentials of microvolt order, named "plant noise," is removed by platinum electrodes [16]. The so-called "plant noise" is evidently related to the oxidation-reduction process.

In the brain of animals and humans, along with a more rapid rhythm [3, 10, 17], superslow BP rhythmic variations also exist (of a minute rhythm), usually within limits of 5-20 mv, with a cycle of 1 -2 minutes [6, 8, 18-20]. The minute rhythm of animals, when removed from electrodes placed at long distances from one other, increases in amplitude [18]. In our experiments we failed to observe any increase in BP rhythmic oscillation amplitude in tradescantia when the distance between electrodes was altered.

Evidently, for the formation of BP rhythmic oscillations, conditions are necessary in which a rapid transposition occurs of positive and negative ions taking part in cell polarization, or else their rapid formation due to the great velocity of the biochemical reaction. Thus, in mental activity the variations in human electroencephalograms are observed toward a marked increase in frequency [3]. From the adduced comparisons of BP rhythmic oscillations, beginning with protozoa and ending with highly developed creatures, it becomes evident that these phenomena have a general biological significance.

SUMMARY

Bioelectric potentials (BP) in plants intimately depend on the vital processes occuring in them and on the environment.

In the spring, during accelerated development of plants, an enhanced electrical activity is observed which is also manifest in rhythmical oscillations of the BP about a constant level. In Tradescantia zebrina, these oscillations are very strong, their amplitude being as high as 10-20 mv and their frequency reaching 100 cycles per hour.

Throughout the spring a characteristic diurnal variation of the BP can be observed in tradescantia. Beginning at about 11 o'clock in the morning rhythmical oscillations of the BP occur which continue until 1 P.M. After 6 P.M. rhythmical oscillations appear again and last until 11 P.M.

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VITAMINS OF THE BIOS-GROUP IN FLOWERS, FRUITS, AND SEEDS OF SOME PLANTS

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Bios vitamins were discovered by Wildiers in 1901 as substances necessary for yeast reproduction. However, at present they are undoubtedly needed also in higher plants, since they are principally accumulated in those plant parts which pass through a stage of meristematic growth, namely in embryos of germinating seeds, in flowering buds, and in cambium. In Söding's words [1] they become activators of metabolism in all organs. The physiological role of individual components of this group is stated in K. E. Ovcharov's monograph [2].

The culminating activity of all living processes in the development cycle of higher plants usually occurs in the flowering phase; plants mobilize all their powers for flowering and fruit bearing, expend an enormous quantity of their food reserves, and some of them sacrifice their lives for this reason (monocarpic plants). Therefore it can be assumed that the bios-group vitamins also accumulate and exhibit an increased activity in plant flowers. However, so far there is little in the literature on this question. To our knowledge, in the Soviet Union only Sukhorukov and Filippov [3, 4] have treated this problem. In one study on cotton plants [3], they showed that when flowers and fruits were removed, the bios quantity in the stems in increased; this means that under normal circumstances some of these vitamins flow from the leaves into the flowers and fruits. But the increased bios content of cotton plant fruits, by comparison with the stem, is found only in light, while in the dark the bios content in fruit is diminished, since its synthesis in the leaves ceases.

In the second study, Sukhorukov and Filippov [4] showed that the bios accumulation in the corolla and ovary of cotton plant flowers differs. In the course of flowering, the bios content in the corolla petals increase at first, then decreases, but in the ovary it increases steadily. From this fact the authors deduce that the bios flows from the corolla into the ovary. In isolated petals no bios decrease was found.

These data stimulated our continuing and widening the study of bios dynamics in different plants. My young co-workers, S. Belyukene, B. Grudinene, B. Sodeikaite and V. Matskevichyute conducted this study from 1947 to 1949. The purpose of the study: 1) a comparison of bios content in flowers and other plant organs taken simultaneously; 2) a comparison of bios content in different parts of the flower, and 3) investigation of bios dynamics in the course of flowering. Partial results of our collective study were published in Lithuanian [5] but remained unknown to wider circles of biologists. For this reason, they are briefly stated here.

Studies were conducted on woody and grassy plants. Extracts were prepared from materials dried at 60° and ground. Either 20 times the quantity of water or 87% alcohol was used for extraction. Extraction was 30 minutes under reflux. Testing for bios content was conducted by the yeast method; the quantity of yeast was determined by counting in a Thoma chamber. Yeast cultures were grown in test tubes in Boas [6] liquid nutrient medium at 26-27°. The tested extract was added to he nutrient medium in amounts of 1 or 5%. The nutrient medium without vitamins served as the control. After 24 hours the growth of yeasts was discontinued by adding 3 drops of concentrated sulfuric acid to each test tube, and a count was made.

As an index of the bios quantity a coefficient of reproduction f was taken, which shows by how many times the number of yeast cells in the culture where a given extract was added exceeds the number of cells in the control.

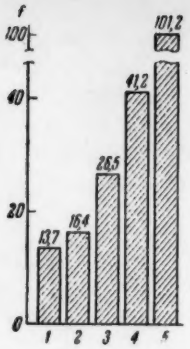

Fig. 1. Bios in buds and blossoms of hazelnut (Corylus avellana L.) 1) Leaf buds; 2) female blossom buds; 3) male compact racemes (catkins); 4) male flocculent racemes; 5) blooming male racemes.

1. Bios Vitamins In Flowers

For tests of woody plants, the following were taken: 1) plants with anemophilous flowers, flowering before the leaves open (Corylus avellan L., Populus nigra L.); 2) plants with entomophilous flowers flowering simultaneously with leaf opening (Acer platanoides L.); 3) plants with entomophilous flowers flowering after leaves develop (Tilia platyphyllos Scop., Caragana, aborescens Lam.).

In experiments with hazelnut, extracts from leaf buds, female flower buds and male racemes (catkins) were prepared at flowering (April 18, 1948), at which time the catkins were taken in 3 phases of development (1) compact, 2) loose, 3) flowering). The bios content is shown in Fig. 1, from which it can be seen that male hazelnut racemes are especially rich in bios. Their bios content gradually increases as they progress to full flowering.

In 1949 we made preparations from component parts of male hazelnut racemes — from catkin axis, scales and stamens, and determined the amount of bios in each separately. The experiment showed that the stamen extract is almost twice as rich in bios as the catkin axis. The scales occupied a median position. By addition of 1% extract the following average magnitudes of reproduction coefficient (f) were obtained.

Catkin axis	21.1
Scales	28.5
Stamens	37.2

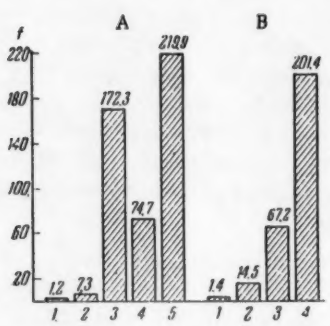

Fig. 2. Bios in twigs, buds and blossoms of black poplar (Populus nigra L.) A) Male tree; 1) twigs; 2) leaf buds; 3) catkin axis; 4) scales; 5) stamens; B) female tree; 1) twigs; 2) leaf buds; 3) catkin axis; 4) pistils.

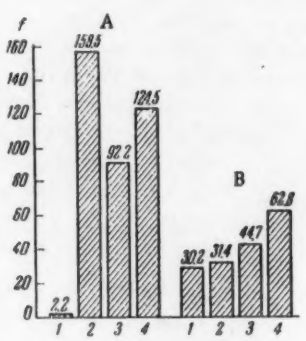

Fig. 3. Bios in twigs, buds and blossoms of sharpleaf maple (Acer platanoides L.). A) Samples taken on April 25, 1948; 1) twigs; 2) leaf buds; 3) peduncles; 4) blossoms.

In an experiment with black poplar, conducted on April 19, 1948, the buds, twig tips, and racemes (catkins) were taken separately from a male and female tree. Preparations were also made from racemes by their component parts.

The bios content is shown in Fig. 2. It appears that in poplars the maximum bios content is also concentrated in racemes and especially in the main portions of the flowers: the stamens and pistils. In twigs only traces of bios vitamins are found, evidently because woody tissue comprises the basic mass of twigs, in which there are few living elements. There is 6-10 times as much bios in the poplar leaf buds as in the twigs, and yet they are poor in these vitamins by comparison with flowers.

The maple (Acer platanoides L.) blooms almost at the same time as the leaves open. On April 25, 1948 small twigs, opening leaf buds, peduncles and flowers were taken from maple. The effect of extracts on yeast

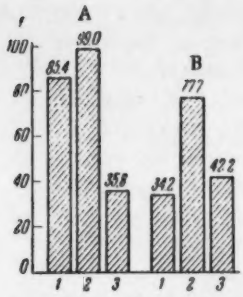

Fig. 4. Bios dynamics in blossoms. A) Apple tree (Malus communis Lam.) and B) pea trees (Caragana arborescens Lam.): 1) buds; 2) opened blossoms; 3) withering blossoms.

reproduction is shown in Fig. 3. It can be seen that the opening buds and leaves show a very high bios content, that a median position is occupied by peduncles, and very little bios is found in twigs. Another sample from the same maple organs was taken on May 7, 1948, when the leaves were already somewhat grown and racemes had withered. In this sample the bios content was considerably smaller; the leaves contained $\frac{1}{5}$ of the bios compared to the opening buds, and the withered flowers contained approximately $\frac{1}{2}$ the bios compared to the young ones. It was concluded from this experiment that the amount of bios is proportional to intensity of meristematic growth. At the beginning of flowering the primary place in bios content was taken by leaf buds, since their meristematic growth exceeded such growth in flowers. In the second sampling the leaves had already passed through the stage of expansion, in which synthesis of organic substances is manifested feebly; therefore there is less need for vitamins. The meristematic growth continues in ovaries of withered flowers, so that the bios content is diminished to a lesser degree than in leaves. The rather high bios content in maple peduncles can evidently be explained by an intensive transfer of bios through them — it is doubtful that they themselves produce these substances.

In trees blossoming after developing leaves, investigations were conducted on apple trees (Malus communis Lam.), pea trees (Caragana arborescens Lam.)

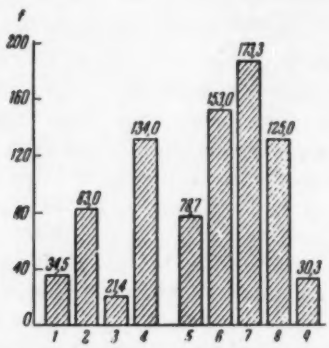

Fig. 5. Bios in different linden organs (Tilia platyphyllos Scop.): 1) leaves; 2) buds; 3) perianth; 4) flowers; 5) calyx; 6) corolla; 7) young stamens; 8) old stamens; 9) pistils.

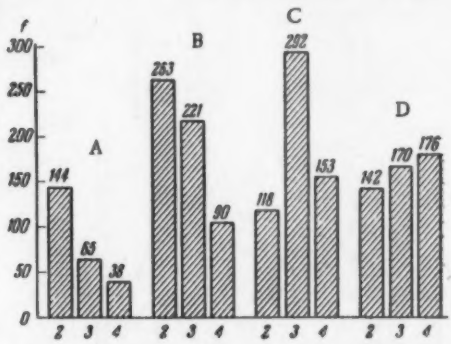

Fig. 6. Bios dynamics in different parts of petunia flower (Petunia violacea Lindl.): A) calyx; B) corolla; C) stamens; D) pistils; 2), 3), and 4) flowering phases.

and linden trees (Tilia platyphyllos Scop.). In all three the flowers contained more bios at the time of fall blossoming by comparison with the leaves. The bios dynamics in flowers of the apple tree and pea trees were investigated at different stages of their development. Extracts of buds, opening flowers, and withering flowers were compared. Maximum bios was found in opening flowers (Fig. 4). This means that the bios continues to accumulate in flowers to full development, and decreases in proportion to withering.

The bios concentration of different organs above ground, as well as its distribution along different portions of the flower, was studied in linden trees. As to the first problem, it was shown that at the time the linden blooms (at the end of June) the bios concentration is greatest in flowers, secondly in leaf buds, thirdly in leaves, and even less in the covering leaves of racemes (Fig. 5). In the individual organs of the flowers, the bios concentration in descending order is stamens, petals, sepals, and pistils. For purposes of comparison we also made an extract of old stamens from withered flowers. The bios content of these was 72% of that in young flowers. From this it can be concluded that the concentration of bios vitamins in flowers decreases upon aging.

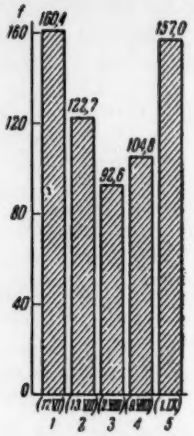

Fig. 7. Bios dynamics in red bilberries (Vaccinium vitis idaea L.); 1), 2), 3), 4), and 5) phases of development.

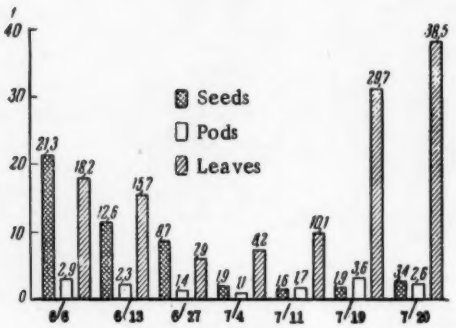

Fig. 8. Bios dynamics in seeds, bean pods, and leaves of pea trees (Caragana arborescens Lam.).

The question arises: where do they disappear? There are two possibilities: the conversion of bios into a bound form, or its flow into other organs. Our subsequent experiments with grassy plants have shown that transfer of bios from some portions of the flower into others is very possible. In two plants of the potato family (Nicotiana longiflora Cav. and Petunia violacea Lindl.) the dynamics of bios accumulation in individual flower parts during different phases of blooming was traced. The material was collected from the same plants at four phases: 1) buds (before they broke up into component parts); 2) petal appearance; 3) flower opening, the petals reaching their full development; 4) withering: stamens spill pollen, corolla withers and falls off.

The results of the experiment with petunias are given in Fig. 6. It shows that the bios dynamics in the calyx and corolla are manifested by a constant decrease of bios concentration; in the stamen bios is found in small amounts in the initial phases; it reaches its maximum in the third phase, and decreases subsequently; the bios concentration in the pistil gradually increases.

It is possible that in all parts of the flower the bios dynamics are manifested in the form of a curve of the optimum or main growth period. Since in our experiment the flower did not open in the initial phases of flowering, the first part of the curve is missing for the calyx and corolla, and the second part is missing for the pistil. The external parts of the flower pass through a growth maximum, as well as a maximum of bios concentration earlier, which corresponds to their age difference. The lack of maximum synchronism indicates that the bios, as aging of organs procees, may flow from the flower's external parts and migrate into central, younger parts.

2. Bios Vitamins in Plant Fruits

We found an increase of bios concentration in petunia pistils at the end of flowering. In this connection the question arose: what are the dynamics of these substances in fruits which are formed from the pistil ovary? We conducted several experiments on this question with succulent and dry fruits.

As representative of succulent fruits, we used fruits of red bilberry, strawberry, raspberry, black currant, and bilberry. The berries were picked at different stages of development, were dried and ground, after which alcoholic extracts were prepared from the dried material.

The largest bios concentration in all berries was found in the initial phases of development. As the berries grew, their stimulating effect on yeast growth gradually diminished. The minimal bios concentration was found in fully grown but unripe berries. Extracts from some berries, for example strawberries and black currants, picked in the unripe state actually exerted an inhibitory effect on yeast reproduction. Evidently, during this phase of development phytocide substances with a protective function [7] accumulate in the fruit.

In the subsequent course of development, as they ripen, berries accumulate bios anew. This increase of bios in ripened berries we explain by autolytic action which liberates some part of the combined bios into the free state. The same phenomenon, as is known, manifest itself in aging leaves before leaf shedding [8 - 10].

For illustrative purposes the typical example of the red bilberry may be taken (Fig. 7). The bios concentration in this berry in the first phase of development is the same as in the fifth phase. The dynamics curve is symmetrical. The symmetry was not manifested in all plants under experiment. For instance, small green strawberries had the highest bios concentration (at a 5% addition of extract f = 89.2), which later markedly diminished (at the minimum point f = 0.25), while on ripening it increased slightly (up to f = 9.1). By contrast, in bilberry the ripened berries had double the bios concentration of small berries at the beginning of development.

Experiments on dry fruit plants were conducted with wild carrots and pea trees (Caragana arborescens Lam.). We collected the carrots at 6 phases of development. The maximum bios concentration was found in green carrots of the first phase. Thereafter for 2 weeks a small decrease of bios occurred, but in the phase of carrot yellowing, an increase in bios concentration almost to the initial level appeared, evidently because of conversion of the temporarily bound bios into the free state. But subsequently, as the carrots dried, a decrease of bios to a very low level again appeared.

In pea trees we investigated bios content separately in the seeds and in bean pods. Simultaneously also, samples of leaves were taken for comparison of bios content. Results are shown in Fig. 8. In the seeds the highest bios concentration was found in the very small seed embryos (June 6). On further development (up to July 11) the bios content in seeds decreased, and at the end of ripening it increased somewhat. There is much less bios in young pericarps (pods) than in seeds (f = 2.9); later its concentration also decreases to a minimum on July 4, while in the drying pods the bios dynamics appear in the same saddle-shaped form of curve, except that by the end of July the increase of bios in leaves appears much more clearly.

This character of bios dynamics we tend to explain by the gradual transition of bios into a bound form during the first half of the vegetation period and its subsequent liberation during the second half of the summer. By autumn an autolysis of proteins becomes manifest in leaves and as a consequence there is liberation of bios. The same thing happens also to the pericarp, which dies off when seeds ripen. A portion of the bios most probably is transferred from the dying pericarp into the seed or the axial parts of shoots. Some bios increase in ripened seeds can evidently be explained by autolysis of protein in the dead seed casings, and possibly the seeds receive an additional bios quantity at the time from dried up bean pods.

3. Bios-Group Vitamins In Germinating Seeds

In the first place, we investigated bios distribution in individual component parts of kidney beans and peas. In both the maximum bios quantity was found in seed embryos; second were cotyledons, and third the seed casings. As an example of the experiment the effect is shown of an added 1% kidney bean extract on the coefficient of yeast reproduction f:

Seed casings	1.11
Cotyledons	3.65
Embryos	7.03

These data confirm my thesis (Dagis [8]), stated previously, that the bios substances are primarily concentrated in the embryonic plant tissues. Later we traced bios changes during the germination period. Kidney bean seeds (Phaseolus vulgaris L.) were germinated in large Petri dishes on moistened filter paper at 22° Samples for bios analysis were taken after 3, 5, 7, and 10 days of swelling. From the samples taken we made preparations of the casings, the cotyledons, and embryos, and made extracts of these. Tests showed that in the casings as they continued to germinate the amount of bios vitamins gradually decreased, while in the cotyledons and embryos they increased up to 5 days after the beginning of the experiment. An especially large increase was shown in the embryos. By an addition of 1% extracts to the nutrient medium the following coefficients of yeast reproduction (f) were obtained: unsprouted seeds—3.22; after 3 days of sprouting—14.55; after 5 days—41.55; after 7 days—30.83; after 10 days—9.50.

As seen from the given data, with increasing germination the bios in the seedling decreases. The same effects were obtained with cotyledons. From this it follows that in seeds the bios reserves present provide for the needs of sprouts only during the period of the first 5-7 days. In subsequent growth the bios vitamins either combine or are used up in some other manner, but their further synthesis in laboratory environments, either for reasons of insufficiency of light or other necessary factors, is incapable of compensating their loss [11].

SUMMARY

The experiments conducted in this study show that the bios vitamins accumulate in large quantities in the reproductive organs: buds, flowers, and young fruit and seeds. The bios concentration in each organ is variable, but varies uniformly; it gradually increases at the beginning of development, attains its maximum in that phase of development where the metabolic intensity in the given organ proceeds at the highest tempo, and then decreases again. The timing of this maximum does not coincide in individual parts of the flower; this affords a basis for the supposition that the bios vitamins are transferred from the perianth into the stamens and pistils and are accumulated in the young fruit [4].

Organic substances do not flow from succulent fruits and seeds into the material organism. The bios substance dynamics in them have a somewhat different character. Two maxima are manifested in them. In fruits the first maximum coincides with the phase of their embryonic growth and the second with aging, when there is autolysis in tissues of the ripe fruit. In seeds one maximum is manifested during embryonic growth and the second druing the period of seed sprouting. Bios vitamins are inactivated at the period of dormancy when they combine with proteins.

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CONCERNING SOME PHYSIOLOGICAL PECULIARITIES OF DORMANT POTATO TUBERS

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Many experiments devoted to clarifying the causes of dormancy in potato tubers have been performed. During their progress many different theories have been developed concerning this problem, however none of them indicate all the variations of the accumulated facts. The inadequacy of these theories, it seems to us, is due to the fact that the authors tried to explain the nature of dormancy on the basis of some one special biological feature of the tubers controlled by some one factor. Thus, the opinions arose concerning the primary importance of a limited or excessive supply of air to the internal tissues of the tubers for the dormant period [1, 2], the specific relationship of substances from the group of growth stimulators found in the tubers [3], the special physiological condition of the protoplasm in the cells around the eyes [4], and the appearance of so-called growth inhibitors in the tubers [5].

It was not the object of the present investigation to thoroughly explain dormancy in young potato tubers and what causes them to emerge from this condition since this would, apparently, be a somewhat untimely problem. However, it seemed quite possible to determine what special physiological features play the most important role.

Hence we undertook this very problem in the present investigation.

MATERIALS AND EXPERIMENTAL METHODS

The work was done in Crimea from 1954 to 1956. The following varieties of potatoes were used in the experiments: Rannyaya rosa, Ul'yanovskii, RK-80, and RK-114. Of these varieties, tubers of Rannyaya rosa are characterized by the longest and most deep-seated dormancy, and PK-114 by the shortest.

Each of the varieties studied were raised using two kinds of agricultural methods: with irrigation and under arid farming. By means of the arid conditions we tried to get some disturbance in the natural progress of the physiological processes which could also lead to a change in the natural period of dormancy which the tubers passed through. The other method of treating the tubers was mechanical injury; this was accomplished by removing the skin.

The tubers were stored in a basement chamber where the air temperature depended very much on the time of the year. For example, from August to October during the day it reached 16 and even 20°, and in the winter months it fluctuated between 5 and 9°. The relative humidity of the air in the basement was kept at 64-89%

In order to obtain comparable results the physiological investigations were carried out, as far as possible, under equal laboratory conditions at an air temperature of 18-23°, and a relative humidity of 60-80%.

Respiration was measured gasometrically in replicates of two using Ors apparatus reconstructed by Yu. B. Rakitin (Arbatskii [6]). The results were expressed in mg CO_2 per 1 kg fresh weight per hour.

The permeability of the tuber tissues to organic substances (exosmosis) was measured according to Sykhorukov's method [7] which we altered specifically for the samples. The results were expressed in ml 0.1 N permanganate per 100 g fresh weight of tubers per 12 hours.

TABLE 1

The Rate of Respiration in Potato Tubers during Storage in 1954

Variety	Growth conditions	Time of experiments	
		freshly harvested Oct. 20	2 mo after harvest, Dec. 16
Ulyanovskii	With irrigation	24.9	7.8
The same	On dry plots	—	12.4
RK - 90	With irrigation	14.2	7 0
RK - 114	The same	23.5	13.3

The absorption and evaporation of water by the tubers was determined by the difference in their weight after they had been in water or in the air for 12 hours. This was repeated in replicates of 4-5. The difference in weight, expressed in grams of water, was based on 100 g of tuber.

A comparable study of the physiological condition of the cell protoplasm in the area of the eyes (lipoid reaction) was made on fixed preparations prepared according to Ciacaccio's method (Roskin [8], Satarova [9]).

EXPERIMENTS WITH ENTIRE TUBERS

We made observations on the condition of the eyes in the potato tubers during their period of storage in 1954/55 and 1955/56. The duration of the dormant period was arbitrarily based on the number of days from the time the potatoes were placed in storage until the beginning of mass sprouting of the eyes in a given sample of tubers.

As a result of these observations it was established that the potato tubers which developed on dry plots began to sprout earlier than the tubers from field conditions. Depending on the variety, the variation between the duration of the dormancy period in tubers from the dry plots and those from field conditions at our conditions of storage amounted to 10-30 days. A similar relationship between the duration of dormancy and the conditions at which the potatoes grew was observed earlier by Kal'yanov [10].

TABLE 2

Respiration of Potato Tubers in Storage in Relation to the Growth Conditions (data obtained Oct. 25, 1954)

Variety	Growth conditions	Rate of experiment	Rate of respiration	Respiratory coefficient
Rannyaya rosa	With irrigation	21.II.55	8.6	0.86
	On dry plots		10.4	1.01
Ulyanovskii	With irrigation	6.II.55	9.1	0.98
	On dry plots		10.2	1.02
RK - 80	With irrigation	21.II.55	9.1	1.29
	On dry plots		8.8	0.85
RK - 114	With irrigation	6.II.55	9.0	0.91
	On dry plots		10.1	0.92

The microchemical studies which we did support the relationships noted above. Using Ciacaccio's fixation method we obtained sufficient variation in the intensity of staining of the cells in the eye zone in the sprouting and dormant tubers. It appeared that the duration of dormancy in the tubers at the same storage conditions depends on the potato variety and the growing conditions. For example, RK-114 began to sprout earlier than Rannyaya rosa, and in the same variety the dormancy period was shorter when the tubers cam from dry plots than when they came from irrigated ones. Consequently, raising potatoes on dry plots as a means of influencing the biology of the tubers proved effective. This was evident in the earlier sprouting of these tubers as compared with those from field conditions.

Is their also a corresponding change in the activity of the physiological processes?

Table 1 contains the data concerning the rate of respiration in potato tubers which developed from the summer planting in 1954.

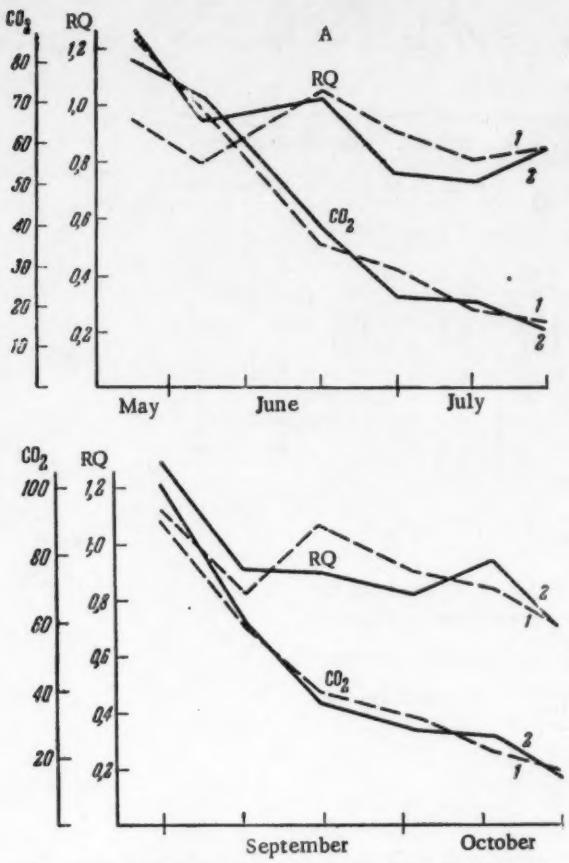


Fig. 1. Rate of respiration (CO_2) and respiratory quotient (RQ) of potato tubers during growth in 1955 on dry plots (1) and with irrigation (2). A) Spring planting; B) summer planting.

The rate of respiration in the tubers during storage was quite low compared to that in the feshly harvested ones. The rate or respiration in Ul'yanovskii tubers raised on dry plots was higher than that in tubers from field conditions. Comparing Ul'yanovskii (from dry plots) and RK-114, we were convinced that during storage their respiratory rate did not vary by much even though the first variety was dormant and the second had begun to sprout.

Further observations on the material from the 1954 summer planting were made in February, 1955; i.e., 102-117 days after the tubers were placed in storage. By this time all varieties, grown on dry plots and with irrigation, terminated their dormancy.

From the data in Table 2 it is evident that in most cases during storage the tubers from dry plots respired more intensively than these from the field. It is true that these difference are very small, and here we can only speak of some tendencies in this direction.

Physiological studies were made on the potato tubers from the 1955 spring and summer plantings during their growth. Fig. 1 contains the data for only one variety of the four potato varieties studied by Ul'yanovskii.

Similar results were also obtained for the remaining varieties — Rannyaya rosa, RK-80, and RK-114 – therefore it is not necessary to present them.

The variation obtained in the respiratory activity of the tubers in relation to their conditions of growth was very small and irregular. We did not obtain a sharp or constant relationship between respiratory activity of the tubers and conditions of growth in our experiments.

During storage the rate of respiration in most of the varieties was somewhat higher in the tubers from the dry plots than in those at field conditions (Table 3).

However, as in the previous year, these variations appeared only in the form of insignificant deviations toward an increase.

The effect which the dry plots had on the degree of permeability of the tuber tissues was expressed by a noticeable increase in exosmosis of organic substances during storage of the potatoes (Table 4).

The higher indices of exosmosis in the tubers from the dry plots were observed not only during storage, but also during growth (Table 5).

It is necessary to note that the effect of the dry plots on the early stages of tuber growth are less distinct than during storage.

Similar results were also obtained in experiments on absorption and evaporation of water by the tubers (Table 6).

Therefore, due to the effect of a factor which shortened the dormancy period of the tubers (effect of drought), a small tendency toward an increase in the rate of respiration during storage of the potatoes was observed.

The permeability of the tissues to organic substances and water as the result of the influence of drought underwent a sharper and more regular change.

TABLE 3

Rate of Respiration (CO_2) and Respiratory Quotient (RQ) of Potato Tubers in Storage in Relation to Conditions of Growth

Variety	Growing conditions	Before storage		Number of days after storage			
				After 35 days		After 3 months	
		CO_2	RQ	CO_2	RQ	CO_2	RQ
Rannyaya rosa	With irrigation	17.7	0.63	8.2	0.73	11.1	0.86
	On dry plots	16.2	0.63	8 9	1.07	17.1	0.82
Ulyanovskii	With irrigation	14.7	0.86	5.3	0.67	5.0	0.61
	On dry plots	17.0	0.87	6.2	0.75	6.8	0.74
RK - 80	With irrigation	12.8	0.76	8.6	0.83	8.4	0.69
	On dry plots	12.7	0.66	6.0	0.63	8.4	0.77
RK - 114	With irrigation	16.0	0.69	7.1	0.72	11.8	1.02
	On dry plots	21.2	0.61	7.9	0.77	12.5	0.59

TABLE 4

Exosmosis of Organic Substances in Potato Tubers from the 1954 Summer Planting in Relation to Conditions of Growth

Conditions of Growth	Rannyaya rosa	Ulyanov-skii	RK - 80	RK - 114
With irrigation	0.68	0.94	0.80	1.26
On dry plots	1.05	1.58	1.10	1.69

Note: The data for Rannyaya rosa and RK-80 obtained February 21, 1955, and for Ul'yanovskii and RK-114 February 6, 1955.

TABLE 5

Exosmosis of Organic Substance in Potato Tubers during Growth at Various Growing Conditions (summer planting, 1955)

Variety	Conditions of growth	Aug. 28	Sept. 9	Sept. 16	Sept. 29	Oct. 7	Oct. 16
Rannyaya rosa	With irrigation	9.31	2.54	0.39	0.46	0.25	0.38
	On dry plots	4.54	2.24	1.02	1.12	0.32	0.40
RK - 80	With irrigation	2,45	1.91	0.32	1.07	0.20	0.23
	On dry plots	2.00	2.21	0.64	1.02	0.43	0.33
		Aug. 31	Sept. 12	Sept. 20	Oct. 2	Oct. 12	Oct. 20
Ulyanovskii	With irrigation	3.46	1.96	0.77	1.08	0.33	0.54
	On dry plots	1.10	2.95	0.80	1.60	0.40	0.76
RK - 114	With irrigation	4.20	2.81	0.57	1 19	0.76	0.59
	On dry plots	3.95	3.38	0.75	1.44	0.82	0.64

TABLE 6

Rate of Water Exchange in Potato Tubers during Growth and Storage in Relation to Conditions of Growth

Variety	Conditions of growth	Growing period					Storage period	
		June 4	June 15	June 24	July 9	July 20	Aug. 25	Nov. 24
Absorption of water								
Rannyaya rosa	With irrigation	3.93	0.52	0.29	0.34	0.21	0.20	0.19
	On dry plots	5.21	0.53	0.26	0.63	0.45	0.21	0.25
RK - 80	With irrigation	4.00	0.73	0.30	0.31	0.35	0.34	0.23
	On dry plots	2.91	0.45	0.26	0.46	0.70	0.45	0.27
Evaporation								
Rannyaya rosa	With irrigation	6.60	1.22	0.50	0.82	0.34	0.21	0.21
	On dry plots	6.53	0.91	0.40	1.47	0.54	0.23	0.24
RK - 80	With irrigation	5.60	1.35	0.54	0.89	0.32	0.24	0.23
	On dry plots	5.00	0.87	0.37	1.12	0.52	0.25	0.27

TABLE 7

The Rate of Respiration and the Permeability of the Tissues during Storage in Potato Tubers Grown under Different Conditions

Determinations	Conditions of growth	Before storage	During storage	
		July 20.	Aug. 25	Nov. 24
Rannyaya rosa				
Rate of respiration	With irrigation	36.9	17.7	20.4
	On dry plots	31.4	12.3	33.2
Exosmosis of organic substance	With irrigation	7.93	3.85	5.41
	On dry plots	11.69	4.45	5.66
Absorption of water	With irrigation	4.55	3.71	5.54
	On dry plots	6.06	3.87	5.31
Evaporation of water	With irrigation	4.53	3.68	5.09
	On dry plots	6.10	3.83	6.04
RK - 114		July 25	Aug. 30	Nov. 27
Rate of respiration	With irrigation	37.5	18.8	22.4
	On dry plots	35.6	29.5	30.7
Exosmosis of organic substances	With irrigation	7.85	10.16	9.59
	On dry plots	8.25	10.84	8.14
Absorption of water	With irrigation	4.87	5.77	6.56
	On dry plots	5.52	6.20	6.65
Evaporation of water	With irrigation	3.91	5.50	4.69
	On dry plots	4.50	6.26	4.87

EXPERIMENTS WITH TUBERS WITHOUT EPIDERMIS

The main principles concerning the physiological processes noted in the experiments with intact tubers remain basically the same in experiments with tubers without epidermis (see Table 7). The tendency toward an increase in the level of physiological activity of potato tubers grown on dry plots was retained. In addition

TABLE 8

Rate of Respiration and Permeability of Tuber Tissues during Storage; Summer Planting 1955 (variety Polivnoi)

Determinations	Before storage, Oct. 16, 1955	During storage	
		Dec. 7, 1955	Jan. 26, 1956
Rannyaya rosa			
Rate of respiration	22.8	21.7	19.8
Exosmosis	4.76	4.81	5.24
Water absorption	4.90	5.07	4.76
Evaporation of water	5.88	5.08	5.29

Determinations	Oct. 20, 1955	Dec. 9, 1955	Jan. 30, 1956
RK - 114			
Rate of respiration	32.5	20.0	14.3
Exosomosis	5.76	9.84	11.97
Water absorption	3.13	4.96	5.38
Evaporation of water	3.15	4.29	4.06

it was easy to see that the given relationship was stronger in respect to the permeability of the tissues than it was in respect to respiration rate.

The material in Table 7 is of great interest in relation to dormancy in potato.

About a month after potato tubers variety Rannyaya rosa were placed in storage permeability of the tissues dropped markedly. At this time the tubers were dormant. On the contrary by this time variety RK-114 had already started to sprout, whereupon its rate of exosmosis and evaporation had increased somewhat in comparison with the previous data. Such an increase in the permeability of the tissues of Rannyaya rosa occurred four months after the tubers were placed in storage, when their dormant period was completed. The rate of respiration had the same relationship only in variety Rannyaya rosa. However, this was not observed for either of the varieties in tubers of the 1955 summer planting (see Table 8).

When comparing the activity of the physiological processes in freshly harvested tubers (Oct. 16-20) with that of the corresponding processes during storage (Dec. 7-Jan. 31), it is necessary to keep in mind that when the winter experiments were performed Rannyaya rosa was dormant whereas RK-114 had already began to sprout by Dec. 9. Nevertheless, the respiration rate of one or another variety decreased equally during storage.

The rate of exosmosis and that of water exchange in tubers of Rannyaya rosa during storage differed very little from that in freshly harvested tubers. In all cases it did not increase significantly. In the meantime the permeability of the tissues in RK-114 on December 9th, when the dormancy of the tubers was completed, was very much greater than it was immediately after harvest. Expressed differently, the termination of dormancy was accompanied by an increase in the permeability of the tissues.

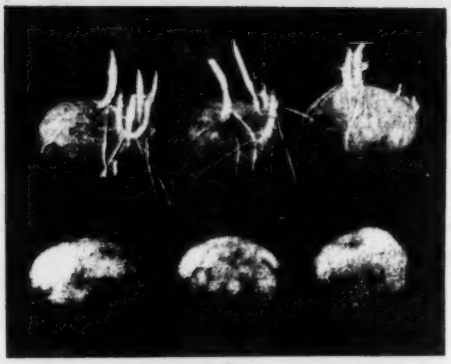
Experiments in which surface injuries of the tuber were washed with water indicate that an increased level of respiration need not always occur in order to interrupt dormancy.

Prokoshev [11] showed that washing the surface of a wound with water retards the wound reaction of the tubers, specifically it inhibits the formation of ascorbic acid by the wound. It would be natural to conclude that such a treatment would also decrease the rate of respiration.

Actually, in our experiments washing the surface wounds with water induced a decrease in the rate of respiration and an increase in the respiratory coefficient.

In order to clarify to what degree washing with water decreased the wound reaction of the tubers it was necessary to clarify what effect it had on sprouting.

By comparing sprouting tubers with washed and unwashed surface wounds we found that the first sprout more readily than the second. In the tubers washed with water the eyes began to sprout somewhat earlier than in the unwashed ones, the sprouts were larger and had more buds (see Fig. 2).



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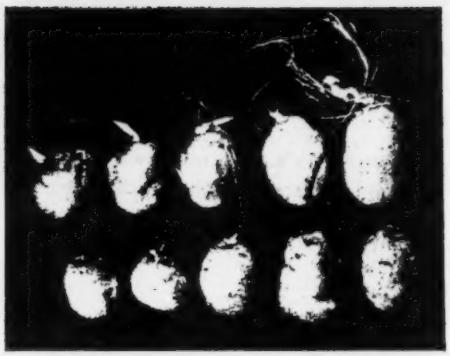

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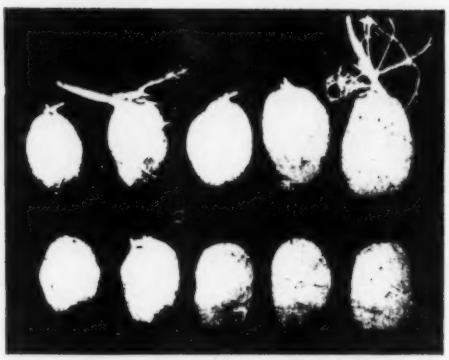

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Fig. 2. Sprouting potato tubers after the skin was removed and the tuber washed (top) and unwashed (bottom). A) Variety Rannyaya rosa; B) variety RK-80; C) variety RK-114

The results we obtained cannot be explained by the possible effect of anaerobiosis or chemical and physical stimulators since the washing did not last more than 3 min and was done under a stream of distilled water which was the same temperature as the surroundings. A more likely explanation can be given based on the assumption that the tubers contain substances which inhibit sprouting during dormancy. According to Hemberg [5] these substances which are soluble in water and either are concentrated on the periphery of the tuber.

Apparently, washing the wounded surface with water helps to remove part of these substances; because of this such tubers sprout earlier and more vigorously than those which were not washed.

DISCUSSION AND RESULTS

On the basis of this physiological study on potato tubers one can specify several conditions which are related to the nature of dormancy.

1. Under conditions which shortened the dormancy period in potatoes (dry plots) we observed only a tendency toward a somewhat increased rate of respiration during storage. However, an emergence of the tubers from the dormant stage need not be accompanied by an increase in the rate of respiration. In the experiments where the wounded surfaces were washed with water the tubers which had the best capacity to sprout were characterized by a decrease in respiratory rate.

This all indicates that the change in the rate of respiration which was observed during the disruption of dormancy apparently does not have just the disrupting effect on dormancy which the adherents of the "oxygen theory" claim [1, 12].

2. The increase in permeability of the tissues observed in our experiments when the tubers emerge from dormancy, as well as the effect of factors which shorten the dormancy period (dry plots), indicates the predominant importance of the colloidal-chemical properties of protoplasm. Therefore, Genkel' and Oknina's [13] point of view, as well as that of Satarova [9] which agree, that the dormancy of the tubers is determined by a specific physiological condition of the protoplasm in the cells near the eyes is of interest. The condition is characterized, in part, by an accumulation of lipoids in the tissues around the eye, and by a low level protoplasmic permeability of the cells which increases when the tubers sprout. This is just what we observed in our experiments.

3. However, it is hard to explain all the aspects of dormancy by means of the special physiological features indicated above. For example, the results of the experiments concerned with the sprouting of washed and unwashed tubers cannot be explained adequately unless we assume the existence of some substances which retard sprouting in the tubers.

4. We propose that the substances which inhibit sprouting of the potatoes do not act alone, but in conjunction with one or another physiological condition of the protoplasm within the cells of the tubers. Therefore our data related to the colloidal-chemical properties of protoplasm and substances which disrupt the sprouting of potatoes indicate a complex of factors which influence the appearance of dormancy.

5. A study of the conditions at which the formation and accumulation of growth inhibitors occurs in the tubers, and their inactivation or destruction is of great theoretical and practical significance. A knowledge of these internal and external factors, and the ability to change them in the required direction will help to develop more effective methods for controlling dormancy in potatoes.

In conclusion I wish to thank P. K. Shkarnikov for his direction and assistance in the completion of this investigation.

SUMMARY

The duration of the dormant state is shorter in tubers of potato plants grown under drought conditions. There is a certain enhancement of respiration in such tubers during storage.

In experiments in which the cut surface was washed with water, tubers with a low respiration rate were found to possess the highest capacity for germination.

The protoplasm permeability of cells near tuber eyes was increased when the tubers were treated in such a way as to reduce the duration of the dormant state and also when dormancy of the tubers terminated.

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SOME SPECIAL FEATURES OF NITROGEN-PHOSPHORUS NUTRITION IN THE COTTON PLANT

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A disturbance in the nutritional or water relations of a plant has a great influence on the morphological-anatomical changes of the plant [1-7]. In addition, and which is especially important, there is a change in the physiological as well as the biochemical processes of the plant organism.

According to the data of some investigators (with various materials and under various growing conditions) it is clear that an increased supply of phosphorus (with a background of NK) brings about an increase in the fraction of phosphorus compounds found in a plant and favors the marked increase in the sugar content [8-16], and as a result the nitrogen content decreases. An increased sugar content during a deficiency of phosphorus was also noted by many authors [10, 12, 17]. Ermolaeva [17] proposed the cause of this phenomenon to be the inhibition of hexose-phosphorus activity because of the phosphorus deficiency, a decrease in the rate of carbohydrate participation in the decomposition processes, and their ever greater accumulation as reserves. Sisakyan [9] and Smirnov [10] also observed an increase in reducing sugars during phosphorus deficiency.

An increased utilization of nitrogen in a plant markedly decreases the content of reducing sugars [18, 19] and the amount of soluble carbohydrates [16, 19, 20, 21] while the content of protein and soluble nitrogen increased.

There are also data [22] which indicate that an abundance of nitrogen increases the rate of photosynthesis, and as a result the plants become enriched with carbohydrates. Dikusar [23] demonstrated that the amount of sugars in 10-day sugar beet increased when the supply of nitrogen was adequate or at a higher concentration. He also indicated that an intensified nitrogen nutrition was accompanied by an increase in the content of reducing sugars. However, Arsanova [24] observed a decrease in the carbohydrate content of cotton leaves before the flowering-fruit bearing period beyond its relationship to the supply of nitrogen. At a later period of growth the variants to which 50-100 kg/hectare of nitrogen were supplied were found to have an increase in the carbohydrate content of their leaves. When 150 kg/hectare nitrogen were added, the carbohydrate content continued to increase right up until the cotton bolls opened. The accumulation and translocation of carbohydrate from the leaves into the reproductive organs at the end of the growing period was more intensified when 150 kg/hectare nitrogen were added, than when 50 and 100 kg/hectare were added.

Many authors [25-27] have also shown that during a deficiency of potassium in the nutrient media the content of carbohydrates drops sharply and the content of soluble nitrogen in the underground parts of the plants increases.

It is necessary to note that there is disagreement in the data of the literature sources that have been cited concerning the effect of mineral nutrition on the physiological processes in the plant. Therefore, further investigations concerning the effect of individual mineral element nutrients on the physiological processes found in a plant are necessary in order to solve the problem of directing the growth of cotton.

TABLE 1

Growth and Reproduction of Cotton at Various Nutritional Conditions, and with the Soil at 65% Total Moisture Capacity

Experimental variants	Height of plants in cm	Number of sympodial branches	Number of reproductive organs					% fluctuation from the total	
			total	components				buds	young fruits
				bolls and young fruits	buds	abscissed buds	abscissed young fruits		
Time of observation - June 9									
O	33.2	6.6	20.2	1.2	18.8	0.2	—	1.0	—
N	45.6	8.2	38.2	1.0	36.8	0.4	—	1.0	—
P	32.8	7.2	21.4	1.0	18.4	2.0	—	9.34	—
NP	53.4	9.4	40.8	1.4	39.2	0.2	—	0.5	—
Time of observation - Aug. 30									
O	42.8	9.0	30.2	9.2	2.6	12.6	5.8	41.7	19.2
N	64.0	12.2	76.5	22.2	31.3	20.2	2.8	26.4	3.7
P	43.4	9.8	31.2	7.2	4.6	15.0	4.4	48.1	14.1
NP	80.0	14.0	95.2	31.2	59.2	15.0	0.8	15.7	0.8
Time of observation - Sept. 13									
O	43.2	9.0	32.0	5.2	—	17.2	9.6	63.7	30.0
N	64.4	14.0	80.8	10.6	—	35.4	34.8	43.8	43.1
P	44.0	9.8	32.0	4.8	–	18.8	8.6	58.7	26.9
NP	80.1	16.0	110.2	20.6	—	45.0	44.6	40.8	40.5

In the present investigation we studied the effect of individual nutrient elements on the growth and reproduction of cotton, and also the phosphorus, nitrogen, and carbohydrate content of cotton leaves, variety 108-F.

The experiment was set up in 1956-1957 at the Institute of Genetics and Plant Physiology, Academy of Sciences, UzSSR, in Tashkent, using vegetative containers with 26 kg of air-dry soil, in replicates of 25.

The mineral nutrients were introduced into the vessels in the form of ammonium nitrate and superphosphate, in amounts of 5 g per vessel added as follows: 1 g before planting, and four additions of 1 g during the growing period.

The present paper contains part of the experimental data obtained in this investigation.

Leaves for analysis were picked from the third layer from the top and killed in Koch's fixative. Bertrand's method was used to determine carbohydrates. Total nitrogen was determined by the micro-Kjeldahl method, protein nitrogen by the Bernshtein method, and nonprotein nitrogen as a difference between the two. Phosphorus was determined by the Fiske-Subbarow method.

All the measurements were made during the following growing stages: 3-4 true leaves, during budding, flowering-fruiting, and at maturity.

EXPERIMENTAL RESULTS

It is necessary to note that even in the budding stage we observed a very noticeable change in the color of the leaves which pointed to a deficiency of one or the other of the mineral nutrients. A detailed description of mineral deficiency symptoms in cotton has been given by Kuper and Donald [28].

From the data given in Table 1 it is evident that the lack of these or other mineral nutrients did not change the total mechanism of growth and the formation of the individual plant organs. These increased from the be-

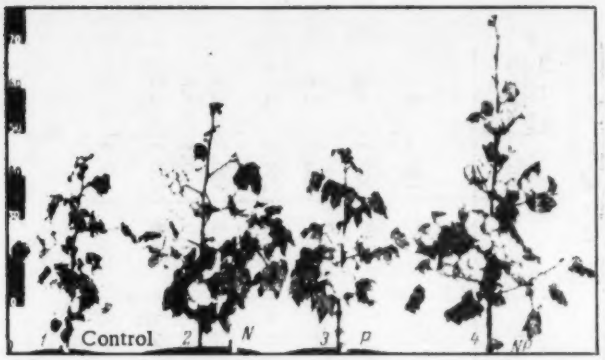

Fig. 1. Growth and development of cotton, variety 108-F at different conditions of nitrogen-phosphorus nutrition (at maturity): 1) without fertilizer (control); 2) fertilized with nitrogen; 3) fertilized with phosphorus; 4) fertilized with nitrogen and phosphorus. Plants grew in soil at 65% of total moisture capacity

ginning to the end of the growing period. But there is a very substantial difference in the absolute figures obtained during the different degrees of fertilizing. However, the plant organs were about the same during the growing period in cotton which had not been fertilized or in that fertilized only with phosphorus. Observations on the ninth of July showed that the variants differed substantially among themselves in respect to growth and reproduction, but during this period there was no difference in the formation of bolls (young fruits) and the abscision of reproductive organs.

During the later observation periods a difference was noted between the variants, not only in respect to growth and total number of fruits, but also in respect to the formation of fully formed bolls and the abscission of the reproductive organs.

The number of bolls which remained on one plant to the end of the growing period under different mineral nutrient conditions increased as follows when compared with those which had not been fertilized: with nitrogen doubted; with nitrogen and phosphorus — four times. The addition of only phosphorus did not have any effect on the formation of bolls as compared to the control plants. Intensive abscission of the buds and young fruits was observed during the height of reproduction (July 30). Whereupon it appeared that the abscission of reproductive organs in cotton which had not received supplementary fertilizer, and in that which had received just phosphorus occurred largely in the bud stage (Table 1).

During a deficiency of nitrogen the cotton plants were low-growing and did not have monopodial stems (see Fig. 1). The cotton plants which exhibited a nitrogen deficiency had an average of 9 sympodial branches and 5 bolls on the bush; these bolls developed at the first node of the lower sympodial branches. During a normal nitrogen supply the formation of bolls was observed on the branches of the low, middle, and top layer (see Fig. 1).

The data concerning the content of phosphorus, nitrogen, and carbohydrates in the leaves of cotton variety 108-F at different levels of nutrition are given in Tables 2, 3 and 4.

As the data in Table 2 show, the highest total phosphorus content was in the leaves of plants which had received supplementary phosphorus, whereupon an increase in all forms of phosphorus was observed up until the flowering stage, except in the second variant; as the plants passed into the reproductive stage the phosphorus content of all the phosphorus forms, and especially the organic, dropped. Apparently this is correlated with the vigorous growth and mass formation of reproductive organs in which the phosphorus compounds are used.

The decrease in the amount of phosphorus compounds occurred less intensively in variants I and III than in variants II and IV. The total number of reproductive organs was almost 2 and 2½ times greater in variants II and IV than in variants I and III. Hence a large amount of phosphorus compounds remained unused in the leaves of variants I and III.

TABLE 2

Phosphorus Content (P_2O_5 in μg per 100 mg dry weight) of Cotton Leaves in Relation to the Addition of Mineral Fertilizer, Soil Moisture at 65% of Water-Holding Capacity (1957 experiment)

Date of collecting samples for analysis and the stage of development	I WF (control) •				II – N				III – P				IV – NP			
	total	inorganic	organic	ratio inorganic to organic	total	inorganic	organic	ratio inorganic to organic	total	inorganic	organic	ratio inorganic to organic	total	inorganic	organic	ratio inorganic to organic
June 1 – before budding	158.5	35.3	123.2	3.5	120.7	34.2	76.5	2.2	197.4	59.8	139.6	2.3	200.0	60.6	139.4	2.3
June 11 – initiation of buds	358.3	154.9	203.4	1.3	337.8	133.9	203.9	1.5	362.7	185.2	177.5	0.95	366.7	174.5	292.2	1.7
June 20 – bud stage	330.6	115.5	225.1	1.9	303.6	93.8	209.8	2.2	366.4	142.8	223.6	1.56	322.0	112.8	209.2	1.8
July 9 – beginning of flowering	311.0	182.5	128.5	0.7	191.0	66.9	124.1	1.85	457.3	254.2	203.1	0.8	361.6	84.8	216.8	2.55
July 10 – beginning of flowering	327.3	200.0	127.3	0.63	185.7	56.6	119.1	2.1	454.5	239.6	214.9	0.9	182.1	73.4	108.7	1.5
July 24 – flower stage	263.5	142.6	120.4	0.84	126.0	42.6	83.4	1.95	326.1	174.6	151.5	0.86	234.4	84.0	150.4	1.8
July 25 – flower stage	259.6	139.5	120.1	0.86	33.9	47.1	85.8	1.82	298.1	175.9	122.2	0.7	263.4	84.9	178.5	2.1
Aug. 2 – mature stage	189.4	67.4	122.0	—	88.2	22.4	65.8	—	278.9	144.1	134.8	—	145.8	35.5	110.3	—

TABLE 3

Nitrogen Content (in mg per 100 mg dry weight) of Cotton Leaves in Relation to the Addition of Mineral Fertilizer, Soil Moisture at 65% of Water-Holding Capacity (1957 experiment)

Date of collecting samples for analysis, and the stage development	I - WF (control)			II - N			III - P			IV - NP		
	total	protein	non-protein	total	protein	non-protein	total	protein	non-protein	total	protein	non-protein
June 1 – before budding	3,65	3.17	0,47	3,8	2,27	0,93	3,56	3,24	0,32	4,29	3,74	0,55
June 11 – initiation of buds	4,6	4,3	0,30	4,88	4,13	0,75	4,19	3,95	0,24	4,67	4,39	0,27
June 20 – bud stage	3,96	3,58	0,38	4,62	4,17	0,45	3,98	3,79	0,19	5,19	4,77	0,42
July 9 – beginning of flowering	3,14	2,73	0,41	4,49	3,71	0,68	2,93	2,46	0,37	3,72	3,2	0,52
July 10 – beginning of flowering	3,00	2,44	0,56	3,77	3,18	0,59	2,82	2,34	0,48	4,18	3,35	0,83
July 24 – flower stage	3,01	2,43	0,58	3,79	2,64	1,15	2,58	2,15	0,43	3,66	2,57	1,09
July 25 – flower stage	2,97	2,69	0,28	3,81	2,86	0,95	2,74	2,19	0,65	4,08	3,31	0,71
Aug. 21 – mature stage	2,22	2,19	0,03	4,0	2,73	1,27	2,57	2,42	0,15	2,88	2,24	0,64

TABLE 4

Carbohydrate Content (in mg per 100 mg dry weight) of Cotton Leaves from Variety 108-F in Relation to the Addition of Mineral Fertilizer, Soil Moisture at 65% of Water-Holding Capacity (1957 experiment)

Date of collecting samples for analysis, and the stage of development	I - WF (control)				II - N				III - P				IV - NP			
	mono-saccharides	disaccharides	starch	total sugars	mono-saccharides	disaccharides	starch	total sugars	mono-saccharides	disaccharides	starch	total sugars	mono-saccharides	disaccharides	starch	total sugars
June 1 – before budding	0.13	0.77	8.94	9.84	0.12	0.7	8.66	9.48	0.14	0.57	7.42	8.13	0.6	1.02	9.47	11.09
June 11 – bud stage	0.84	1.21	6.38	8.43	0.78	0.32	5.81	6.91	0.54	1.52	8.29	10.35	1.08	1.62	7.58	10.28
July 9 – beginning of flowering	0.54	2.66	10.12	13.32	0.12	4.52	10.71	15.35	0.34	2.47	10.59	13.40	0.44	3.37	10.09	13.90
July 24 – flower stage	1.05	1.79	8.72	11.56	0.90	2.03	10.37	13.30	0.49	1.39	7.95	9.83	1.02	1.84	5.3	8.16
July 25 – flower stage	0.38	2.56	9.78	12.72	0.13	2.84	7.96	10.93	0.21	2.43	6.78	9.42	0.32	2.09	6.65	9.06
Aug. 21 – mature stage	0.30	1.96	5.44	7.80	0.08	1.49	5.75	7.32	1.07	1.05	5.76	7.88	0.41	2.85	4.61	7.87
Aug. 22 – mature stage	0.72	1.98	3.35	6.05	0.14	–	6.65	—	0.77	1.15	4.56	6.48	1.33	2.25	6.18	10.86

The highest organic phosphorus content was found in the leaves of cotton plants which had received supplementary phosphorus fertilizer (var. III and IV). The highest ratio of organic phosphorus to inorganic phosphorus was found in variants II and IV, whereupon this increase, as a rule, reached its peak during the bud stage. The content of inorganic phosphorus in the leaves from variants II and IV was less than it was in the control plants (Table 2).

The real cause of this high amount of inorganic phosphorus in variant I, as compared with variants II and IV, was the retardation of growth which was observed in the second half of the growing period. In variant III the increase in the total phosphorus content of the leaves occurred as the result of the inorganic phosphorus. On this basis we conclude that phosphorus transformation into organic forms occurred slowly in the leaves of variant III.

Zuev and Golubeva [12], using P^{32}, also showed that sprouts which were depleted of nitrogen and which received no more nitrogen were characterized by a low phosphorus content in all the fractions of organic compounds.

From the data in Table 3 it is evident that the cotton leaves in variants II and IV had a higher content of all forms of nitrogen at all stages of development than the cotton leaves in variants I and III. It is necessary to note that in variant II the amount of nitrogen was less than in variant 4. The amount of nonprotein nitrogen up until the end of the experiment was higher in leaves from variant III. The amount of protein nitrogen, on the otherhand, was greater in the leaves from variant IV.

However, it is necessary to note that in the bud stage and here in variants II and IV the content of all forms of nitrogen dropped in spite of receiving supplementary fertilizer during the growing period. In variants I and III the decline in the different forms of nitrogen at the beginning of flowering was practically not noticeable (Table 3). This apparently can be explained by the vigorous growth of cotton with nitrogen and nitrogen-phorphorus fertilizer (Table 1). The high retention of different forms of nitrogen, especially protein nitrogen, during growth in variants II and IV occurs as the result of the dynamic equilibrium of protein metabolism, i.e., in the unending processes of the dissimilation of protein compounds, part of them are compensated by the new formation of proteins. In variants I and III, when there was a lack of growth (Table 1), the synthesis of protein nitrogen ceased; and in turn its utilization occurred more slowly.

The data concerning the carbohydrates are given in Table 4.

From Table 4 we see that in many cases a greater amount of soluble sugars (mono- and disaccharides) and starch were present in the leaves from the variants which had not received fertilizer. This phenomenon can be explained by the fact that during a deficiency of nutrient elements (N and P_2O_5) the synthesis of other organic substances is retarded. Therefore the carbohydrates accumulate in the plants. Ermolaeva [17] gave a similar explanation of this phenomenon.

In cotton plants which had received only supplementary applications of nitrogen (var. II) the amount of soluble sugars (mono- and disaccharides) and starch present during the bud stage was less than that in plants from variants I and III. Furthermore, the picture was reversed, with the exception of monosaccharides (Table 4). This can be explained by the fact that the excessive dose of nitrogen brought forth an increase in the amount of it present in the leaves (Table 3). Whereupon it is possible that the excessive amount of sugar would be used immediately in the formation of other organic compounds, including the synthesis of phosphoorganic compounds (Table 2) and protein nitrogen (Table 3). During the further vegetative growth of plants from variant II growth in height became retarded and an intensive formation of new leaves occurred (see Table 1 and Fig.). In addition to this, apparently all the physiological processes become more intense and the sugar content rose.

The large quantity of disaccharides present in the leaves (var. II and IV) can be explained by the very high content of inorganic nitrogen (Table 3). This indicates that the synthesis of proteins is retarded when the plants are supplied with a high dosage of nitrogen (especially nitrogen alone).

The decline in disaccharide and starch content of the leaves toward the end of the vegetative period (especially in variants I and III) can be explained by the transformation of part of the sugars depending on the age of the plant into more complex forms of carbohydrates (hemicelluloses, cellulose, etc.).

The increase in monosaccharide content observed toward the end of the vegetative period (Table 4) agrees with the data of several other authors [9, 10, 29, and others], who attributed this to the slow movement of assimilates from the leaves into the other organs.

SUMMARY

1. A supplementary application of a nitrogen-phosphorus fertilizer had the most favorable effect on the growth of cotton, on the development of leaf area, and the increase in the number of sympodial branches, fruits, and total yield. Phosphorus fertilizer alone did not have this effect.

2. During the cultivation of cotton it is necessary to avoid a nitrogen deficiency since this leads to a premature cessation of growth and plant development, a decrease in size of the bushes, and a sharp decrease in the yield of cotton fiber.

3. The application of nitrogen fertilizer together with phosphorus fertilizer during an optimal moisture supply in the soil (65%) markedly improved the water relations of a plant and favored a higher rate of physiological processes which in turn resulted in a high productivity and plant yield.

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PHOTOSYNTHESIS IN TOMATO PLANTS RENDERED COLD RESISTANT BY PRESOWING TREATMENT AT VARIABLE TEMPERATURES

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Several papers have been devoted to a study of the aftereffects of alternating temperatures on swollen seeds of thermophilic plants [1-6]; in these it was established that the results were the hardening of plants to low temperature, as well as a favorable effect on the productivity. When the temperature of thermophilic plants is lowered the decline in the rate of photosynthesis or the cessation of this process plays a role which cannot but affect their productivity. We have concluded that the comparatively high yield from hardened plants under unfavorable conditions is due primarily to the peculiar activity of their photosynthetic apparatus (associated, of course, with the changes of many aspects of metabolism).

An investigation of photosynthesis in plants hardened with variable temperature has, until recently received little attention.

In 1956-9157, in Dalmatovo (Kurgansk region), one of the authors made a study of photosynthesis in tomato plants which had been hardened by variable temperatures according to A. E. Voronova's method. The design of the experiments, the method of presowing hardening, and the conditions at which the plants were grown, as well as the method for measuring photosynthesis, and the results of several experiments have been described in an earlier paper [6]. The present paper is devoted to a study of the daily rate of photosynthesis in hardened tomato plants under natural conditions.

Photosynthesis was measured by the accumulation of organic carbon in the leaves in the light according to the method described by Borodulina [7]. The following merits of this method were important in our study: the ability to measure photosynthesis in the field at naturally accurring temperature variations on leaves still attached to the plants with many biological duplications. S. S. Baslavskaya, who made a thorough study of the method, found that it yielded accurate results for carbon content only with substances which were related to carbohydrates according to their degree of oxidation, and also indicated several merits of this method in relation to the feasibility and difficulty of its use, and concluded that it is quite suitable for determining the photosynthetic activity of plants [8].

The nature of our determinations was as follows: a) in order to determine the actual rate of photosynthesis the translocation of assimilates from the leaf was measured; b) in order to measure the carbon content of the leaves diphenylamine was replaced by the phenylanthranilic acid [6, 9].

In 1957 experiments with tomato, variety Talalikhin, were run about once every two weeks. The accumulation of carbon, which indicates the daily course of photosynthesis, was measured four times a day at three hour intervals: from 6 to 9, from 9 to 12, from 12 to 15, and from 15 to 18. The results are given in the form of a graph with hours of the day along the abscissa, and apparent photosynthesis expressed in mg carbon accumulated in three hours per 100 cm^2 of leaf area along the ordinate. The accumulation of carbon by the leaves in the light represents the general equilibrium in the accumulation of organic compounds (the difference between the formation of assimilates and their translocation into other organs as well as their utilization in respiration); it can be called apparent photosynthesis. In order to determine the synthesis of organic compounds during photosynthesis in the course of a day the total utilization of carbon and its translocation from the leaves was measured over a

TABLE 1

Weather Conditions at the Time of the Experiments

No. of expt.	Date	Air temperature during the day			Illumination
		Average	minimum	maximum	
1	June 11	18.6	13.2	23.8	Cloudy with clearings
2	June 26	15.7	5.0	22.8	Cloudy
3	July 9	20.8	17.6	24.7	Hazy
4	July 23	16.7	3.6	25.6	Hazy

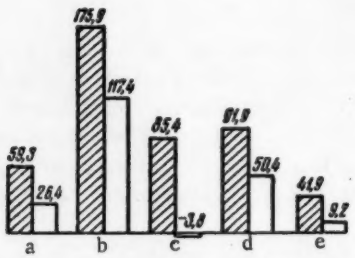

Fig. 1. Photosynthesis in tomato variety Talalikhin (in mg carbon accumulated per 1 in^2 of leaf area during a 12 hr period). a) June 3, vegetative stage; b) June 11, experiment 1, bud stage; c) June 26, experiment 2, flower stage; d) July 9, experiment 3, reproductive stage, (fruits green); e) July 23, experiment 4, reproductive stage (fruits ripe); a, c, d) true photosynthesis, b) apparent photosynthesis; bars at the left - photosynthesis in hardened plants; at the right - in unhardened plants

period from 6 A.M. to 6 P.M.; this made it possible to calculate the true rate of photosynthesis over 12 hours. It was difficult to compare the rate of photosynthesis during the different stages of growth because of the unequal light conditions over a long period of illumination, therefore a diagram was used to illustrate the fluctuations in the rate of the process during the ontogeny of the plant instead of a graph.

Let us examine the data of the individual experiments concerning the daily course of photosynthesis; these show the difference in the activity of the photosynthetic apparatus in hardened and control (not hardened) tomato plants during the course of a day under comparatively severe weather conditions (Table 1).

In our experiments the total value for true photosynthesis in the course of a day was found to be considerably higher in the hardened plants than in the unhardened ones at all stages of growth (Fig. 1).

Experiment No. 1 was performed on June 11; the plants were in the budding stage. During the hours of the experiment the clear weather was replaced by cloudy weather; the temperature was favorable for plant growth (Table 1). The daily course of photosynthesis is plotted in Fig. 2a. In the morning (from 10 until 13) the accumulation of carbon was more intensive in the unhardened control plants. The typical depression of photosynthesis was observed in both variants, but it was less marked in in the hardened ones. In the evening also the hardened plants were more active than the controls. The total accumulation of carbon from 6 A.M. until 6 P.M. was 117 mg/in^2 in the controls, and 175 mg/in^2 in the hardened plants (Fig. 1 b).

Experiment No. 2 on the 26th of June set up during flowering differed very markedly from the previous one in respect to temperature (Table 1); the night before the experiment the minimum temperature was only + 7°, the day was warm (max. 22.8°) with fluctuating clouds. During the morning and midday hours only the hardened tomatoes fixed carbon; from 3 P.M. until 6 P.M. photosynthesis occurred only in the controls; during this period there was only a loss of carbon from the hardened plants in which photosynthesis had been occurring all day (Fig. 2 b). This experiment showed that the sharp drop in temperature the previous night indirectly affected the daily course of photosynthesis, and had a different effect on the hardened and unhardened plants. The rate of photosynthesis was depressed considerably less in the hardened plants than in the unhardened ones. The total values for true photosynthesis were as follows: in the control plants the translocation of assimilates amounted to 38 mg carbon per 1 cm^2 over a period of 12 hours (from 6 A.M. to 6 P.M. in the hardened plants the accumulation of assimilates occurred; namely, 85 mg CO_2 per 1 in^2 (Fig. 1 c).

Experiment No. 3 of July 9th was set up during the fruit-bearing stage (fruits green) and took place under weather conditions similar to those in experiment No. 1, i.e., there was a cool day after a comparatively warm night (Table 1), but the first experiment took place during alternating cloudy and sunny periods and the experiment described below occurred during hazy weather. The midday depression of photosynthesis in this case occurred in the control tomato plants; in the hardened plants this depression occurred at 3 P.M.; the course of photosynthesis (Fig. 2 c) in both groups of plants resembled that described above for the first experiment.

Experiment No. 4 was set up on July 23 when the fruits were beginning to ripen. The night before the experiment the temperature dropped to + 3.6°, therefore it is no wonder that the course of photosynthesis on this day was similar to that in the second experiment which was also set up after a cold night (see Fig. 2, b and d). In the second experiment the difference between the course of photosynthesis in the control plants and that in the hardened ones was expressed even more clearly than in the fourth experiment; perhaps this was due to the difference in the conditions of the plants because of their different stages of growth.

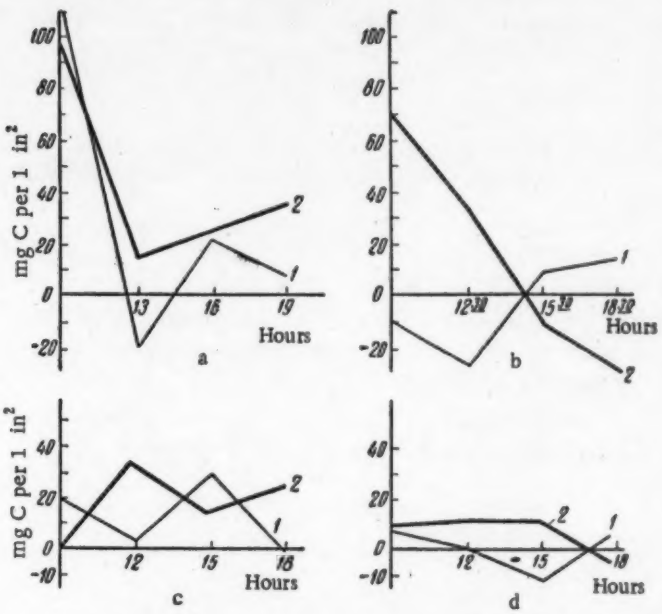

Fig. 2. Daily course of apparent photosynthesis in tomato, variety Talalikhin, in mgC accumulated during three-hour intervals per 1 in^2 of leaf area. a) Experiment 1 (June 11); b) experiment 2 (June 26); c) experiment 3 (July 9); d) experiment 4 (July 23); 1) control plants; 2) hardened plants.

The sensitivity of photosynthesis to temperature was closely related to illumination: the overall rate of the process at high light intensities is due to a temperature factor. The effect of temperature on the rate of photosynthesis is primarily associated with the dark stage of photosynthesis, with its "protoplasm factor", a problem which has been investigated comparatively little. It is known that temperature affects not only the photosynthetic mechanism and the rate of photosynthesis, but also other processes which occur in plants; therefore the relationship of photosynthesis to temperature is a very complex one. Our experiments served to emphasize once more that under natural conditions the daily course of photosynthesis depends not only directly on the immediate effect of the external environment, but also indirectly, i.e., it is related to the changes in physiological conditions of the plant.

From the data in the literature concening the rate of photosynthesis in plants which differ in respect to their cold hardiness it is evident that thermophilic plants immediately after exposure to low temperatures are not able to photosynthesize, or else the ability is very weak and becomes reestablished much slower than it does in cold-resistant species (10, 11, 12). In the unhardened control plants we observed the same phenomenon, whereas in plants grown from seeds which had been hardened before sowing with variable temperatures, the photosynthetic process was characterized by a resistance to cold. The data obtained during a study of thermophilic plants exposed to injurious temperatures are of importance in explaining the difference between the photosynthetic mechanism of hardened and unhardened plants, i.e., those more cold resistant, and those less resistant.

Genkel' and Margolina [13] ascertained that during severe chilling of some thermophilic plants the disintegration of chlorophyll increased, apparently as the result of its dissociation from the protein, whereupon the total amount of chlorophyll decreased; consequently they concluded that chilling brings about a disruption in the protoplasmic structure, in particular that of the chloroplasts.

Dissociation of chloropolasts was disclosed with the use of a phase-contrast microscope in most of the chlorophyll-containing cells in the leaves of the subtropical plant Agava sisalana after chilling to + 3° [14].

It might be concluded that one of the causes of the increased resistance of photosynthesis to lowered temperature which we observed in our tomato plants hardened with variable temperatures is the great cold resistance of their chloroplasts.

SUMMARY

1. The relationship of the rate of photosynthesis in the compared variants changed during the course of the day; this emphasized the need of measuring the entire course of the process when studying it under natural conditions.

2. The overall photosynthesis during 12 hours was considerably higher in the hardened tomatoes than in the unhardened ones at all the stages of growth.

3. The night drop in temperature (+ 3° to + 5°) decreased the rate of photosynthesis 5-20 times more in the unhardened tomato plants than in the hardened ones, i.e., presowing hardening of the seeds increased the cold resistance of the photosynthetic mechanism.

4. The increase in cold resistance of photosynthesis by presowing hardening of thermophilic plants is, evidently, a very important factor in increasing their crop productivity.

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** See English Translation

PROLONGATION OF THE DURATION OF THE BOND BETWEEN ASSIMILATED CARBON AND ASPARTIC ACID

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In spite of the generally accepted concept that the carbohydrates precede all other compounds, in particular proteins, in the process of photosynthesis, the history of photosynthesis has witnessed a number of denials that carbohydrates are necessarily the primary products [1-5]. Levshin [1, 2] particularly clearly expressed the idea that in the process of photosynthesis the first compound synthesized is the protein of chloroplasts.

In recent years, in the course of studying the products of dark fixation by leaves of higher plants [5], as well as the products of photosynthesis during illumination by light of different qualities [6], and by growing plants in varying conditions of nitrogen nutrition and water regime [7], we have obtained experimental data which cause us to join Levshin in his opinion of the possible role of the products of protein metabolism in the photosynthetic process, beginning with a primary bonding of assimilated carbon dioxide and protein [6]. It has been shown experimentally that a large part of the carbon dioxide fixed in the dark reactions of photosynthesis, as well as during short exposures to light, is bound with amino acids, among which the first, and most highly labeled, is aspartic acid. One may suppose that the path of the carbon found in aspartic acid, in the dark and in the light, begins without participation of pyruvic acid [5, 8].

In connection with the question of amino acid participation in the process of photosynthesis the investigations of Warburg are particularly interesting; he has shown that "functional carbon dioxide" is formed in the process of decarboxylation of glutamic acid, connected with chlorophyll, with the simultaneous formation of γ-aminobutyric acid [9]; this reaction was shown to be reversible; the conditions governing this process were found [10]. Warburg's observations on the distribution of labeled carbon have shown that even in thirty seconds after weak illumination, a greater activity was found in aspartic acid and alanine than in the phosphorus esters of carbohydrates; the authors considers that there is considerable reason to believe that a catalytic chain of amino acids is active in the process of photosynthesis [11]. One should not fail to note that the rapid incorporation of carbon into amino acids in the course of photosynthesis has also been observed by other workers [12], but attracted no further attention.

Recently, two communications have appeared in the literature, in one of which [13] are given data on the presence of loosely bonded amino acids in the protoplasm of chloroplast grana, among which glutamic acid is prevalent. In the second [14], information is given concerning the ether-soluble fraction of the chloroplast grana fragments of spinach, in which compounds were found containg aspartic and glutamic acids, glycine and alanine, along with lecithin and cephalin. The authors propose that the amino acids contained in the phosphatide fraction are bound with its substances through an acetylphosphate bond, while the amino groups are left free. Thus, there is experimental evidence of the presence in the chloroplasts—the organelles of cell adapted to photosynthesis— of loosely bound amino acids with free amino groups, capable of combining with a number of substances, carbon dioxide among them.

In previous communications we have shown that the carbon fixed in the process of photosynthesis is first bound with aspartic acid and only later is found in sucrose. In the present work, it has been planned, by combination of various intensities of illumination and lowered temperature, to increase the duration of the existence

of the primary bond between assimilated carbon and amino acids, particularly with aspartic acid, i.e., to postpone the time of incorporation of the carbon into sucrose.

The investigations of the effects of various temperatures on photosynthesis are well represented in the literature, and had a great part in our understanding the chemistry of this process. Nevertheless, using labeled carbon, which allows one to work with short exposures, we succeeded in observing correlations, previously missed by other investigators, not only in the process of distribution, but also in the general uptake of carbon at various temperatures.

EXPERIMENTAL PARTS

The work has been carried out with the leaves immediately above the cotyledons in seven-day-old plants of "shcherdraya" kidney bean, grown in soil in the greenhouse, with additional illumination with daylight fluorescent lamps. In order to avoid the effects on photosynthesis produced when leaves were suddenly placed in chambers of a different temperature, the plants were separated into three groups, and, one day before the experiment, were placed in the dark at atemperatures of 7, 22, and 37° for 19 hours.

Previous observations have shown that at 37° the external signs of leaf injury begin to appear only after 24 hours as infiltration spots; at 7° no visible injury was observed, even after six to seven days of treatment. In connection with the relatively greater resistance of kidney bean to the lower temperature, a treatment was added to the experiment, in which the plants were cooled at 7° for 62 hours, after which they were planted and placed at the low temperature correspondingly earlier. The leaves were separated from the plants immediately before exposure to $C^{14}O_2$ and were exposed at the same temperature at which they were previously kept. Exposures were carried out in a chamber with 3% CO_2, including 0.96% of labeled carbon, at two light intensities: very weak, of the order of 400 lux, and at 10,000 lux. The duration of exposures at each illumination was: 10 seconds, 1 minute, 3 minutes, and 9 minutes. The material was fixed with 80% boiling ethanol for 1 minute and fractionated by the scheme described previously [7].

The effect of temperature on the general uptake of carbon and its distribution among substances of the alcoholic fraction of leaves was determined.

Uptake of carbon. The relationship of carbon uptake by the leaf to temperature with weak illumination is given in Figure 1, A and B. As could be expected, the most intensive uptake of carbon dioxide took place at 37°. But at 22°, during all four exposures, the uptake was less than at 7°. Such an unexpected effect may have been the consequence of the preliminary stay, before exposure, at the lower temperature and in the dark. The correctness of such an explanation is supported by the fact that the rate of carbon dioxide absorption is increased when the plants are kept at the lower temperature from 19 to 62 hours (Figure 1, A, curves 3 and 2). There are communications in the literature concerning an increase in the rate of CO_2 absorption and the formation of organic acids by succulent plants when the temperature of the surrounding medium is lowered [15, 16].

With intense illumination (10,000 lux) such deviations are not observed. Here, a regular increase of the rate of carbon dioxide absorption by the leaf takes place with increase in temperature (Figure 1, C and D). Here, attention is attracted by the fact that as the temperature increases, the absorption rate increases more rapidly with prolongation of exposure (Figure 1, C) i.e., the effect of temperature is less pronounced at shorter exposures (Figure 1, D).

The effect of temperature on the change in the rate of carbon dioxide absorption is particularly indicative if the rate increase is compared at temperatures from 7 to 22°, and from 22 to 37°, i.e., as the temperature changes by 15° (Q_{15}). It turned out that the temperature coefficient, Q_{15}, changed very little in all exposures investigated with weak illumination, and in both temperature intervals fell within the limits of from 1 to 2. However, with intense illumination the temperature coefficient is changed in relation to exposure from 1 to 10 (Figure 1, E). With short exposures (up to 3 minutes) it is considerably higher over the temperature interval 22-37°; with an exposure of 9 minutes, the Q_{15} is higher at the zone of 7-22°. There is much data in the literature indicating that the temperature coefficient is higher at low temperatures than in the interval of higher temperatures. In our experiments, it was noted that the temperature coefficient increases with prolongation of exposure up to 9 minutes in the zone of 7-22°, and that the Q_{15} increases only up to three minutes exposure in the zone 22-37°.

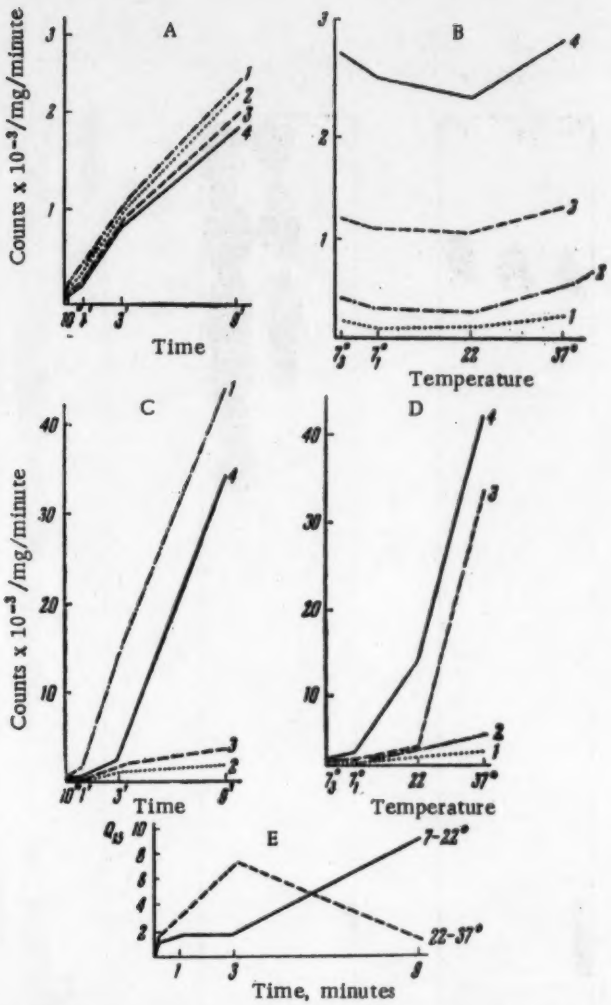

Fig. 1. Effect of temperature on uptake of carbon dioxide by kidney bean leaves. A and B) Light, 400 lux; C, D, and E) light, 10,000 lux. A and C) 1) Approximately 19 hours at 37° 2) 62 hours at 7°; 3) 19 hours at 7°; 4) 19 hours at 22°; B and D) exposure to $C^{14}O_2$; 1) 10 seconds; 2) 1 minute; 3) 3 minutes; 4) 9 minutes; 7°_{3}) Preliminary treatment for 62 hours at 7°; 7°_{1}) the same for 19 hours; E) change of temperature coefficient in relation to exposure time.

Distribution of carbon. As has been shown by chromatographic analysis of the alcohol fraction, with weak illumination at all exposure times, about half of the carbon fixed at 7° is found in aspartic acid, while the other half is found in malic acid (Fig. 2), which is probably connected with its fixation by α-amino acids. At 22 and 37°, the radioautograph of the carbon fixed in malic acid develops very weakly, while the main mass of carbon is found in aspartic acid.

After exposure to strong light in the zone of the same temperature (22 and 37°), a very rapid increase in photosynthesis occurs, particularly in the period from 3 to 9 minutes; during this period an intensive formation of labeled carbohydrates, amino acids, and other compounds takes places (Figure 2, B, C), in complete correspondence with data obtained earlier [7]. The examination of radioautographs of chromatograms after exposure

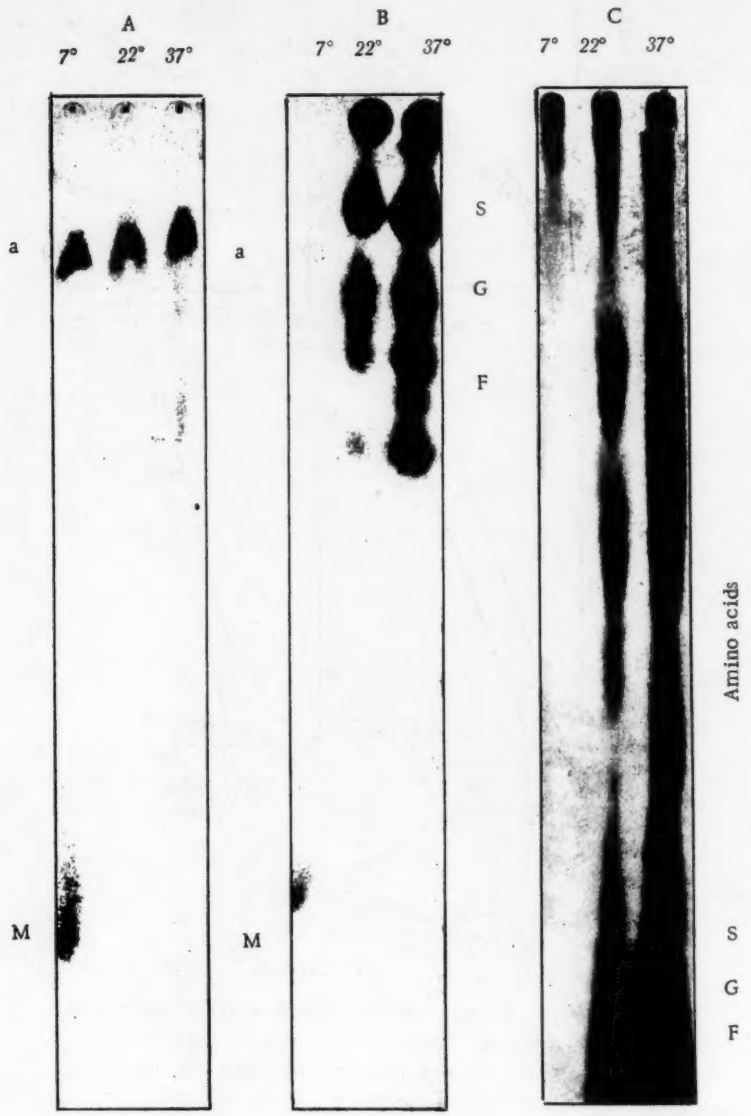

Fig. 2. Radioautograph of alcohol fraction chromatogram after development in a butanol-formic acid mixture, showing the distribution of carbon at various temperatures. A) At 400 lux; a) aspartic, m) malic acids; B) at 10,000 lux. S) Sucrose, G) glucose, F) fructose. C) Radioautograph of chromatogram after separation of amino acids from carbohydrates in 85% ethyl alcohol.

of plants to bright light, but at 7°, shows that the absorbed carbon is found in aspartic and malic acids with exposures from 10 seconds up to 9 minutes. Thus, using the effect of lowered temperature, it is possible to postpone the synthesis of carbohydrates, increasing the duration of existence of the bond between labeled carbon and one of its intermediate products—aspartic acid—up to 9 minutes. These data confirm the possibility of the role of aspartic acid as an intermediary product in the process of photosynthesis, and raise the new question of its precursor.

The incorporation of labeled carbon into aspartic acid undoubtedly may proceed through the well-known path of amination of α-ketoacids or other organic acids [17, 18]. However, there is a basis for belief in the

existence of another path for the synthesis of aspartic acid – through carboxylation of another amino acid, particularly β-alanine.

To prove the possibility of formation of aspartic acid from β-alanine, one would wish to set forth the data concerning its decarboxylation, but, unfortunately, there are no such data for higher plants. The reverse decarboxylation of glutamic acid [10] with formation of γ-aminobutyric acid is relatively well-investigated. One might suppose that finding the conditions for the occurrence of the analogous reaction for aspartic acid could correspondingly lead to the formation of β-alanine. The decarboxylases of amino acids in microorganisms and in animal tissues are considerably better know [19-22], while a decarboxylase of aspartic acid has been shown to be present in microorganisms, leading to the formation of β-alanine, as a result of removal of the carboxyl group next to the amino group.

Preliminary experiments, which we made with the participation of G. A. Slobodskaya, have shown that immersion of roots of eight-day-old kidney-bean plants in a 0.0002 M solution of β-alanine results after several hours in a more intensive formation in the leaves of aspartic acid in the dark, and of carbohydrates in the light, as determined by chromatographic methods. This agrees with data in the literature [23] concerning the positive effect of amino acids, β-alanine among them, on sucrose synthesis. All of this points to the necessity of seeking the conditions for the reaction leading to aspartic acid formation in the process of β-alanine carboxylation.

β-Alanine is interesting not only as a possible precursor of aspartic acid, but also as a component of substances of biological importance—anserine, carnosine, and pantothenic acid. The latter is a growth substance, synthesized in plant leaves only in the light, which occurs both in the free state and bound with coenzyme [24, 25]. In recent years, communications have appeared concerning the occurrence in plants of β-alanine in the free state, as well as in the composition of peptides [26-28]. All this speaks concerning the possible role of β-alanine in the synthetic processes of the cell.

In complete correspondence with the views of Levshin [1], and with data of later investigation carried out with the method of labeled atoms [5-7, 29-31], there is a basis to suppose that carboxylation of β-alanine with consequent formation of aspartic acid occurs not in a free state, but in the form of a complicated complex, which, in turn, affects this process by the peculiarity of its structure, the nature of its components, and the direction of enzymatic processe, conditioned by the adsorbing properties of its surface [32]. Thus, we believe that carbon is incorporated into the first visible product of CO_2 fixation—aspartic acid—which we always found in the dark and with weak illumination [5], in strong light at short exposures [7], and even at long exposures but at low temperatures, as has been shown in the experiments described above. Together with this, a large number of investigators has shown that the first sugar formed in the process of photosynthesis is sucrose [32-35], which was also confirmed in our experiments [7]. How, then, can we connect these two links of carbon dioxide assimilation, which are experimentally demonstrated? For this, as yet, we do not have data either from the literature or from experiments.

SUMMARY

1. The data obtained confirm that carbon is first bound with aspartic acid in the pathway of photosynthesis transformations. Exposing plants at lowered temperature, we succeeded in prolonging the duration of the bond between labeled carbon and aspartic acid up to 9 minutes. By this time, at a higher temperature, with a considerably higher rate of photosynthesis, a larger part of the labeled carbon reached the sucrose stage. At a lowered temperature the carbon, as in the dark, is distributed between aspartic and malic acids.

2. At low illumination, the increase in CO_2 absorption with increase in temperature, Q_{15}, at all exposures is changed within the limits of from 1 to 2. With increase in illumination, the Q_{15} changes from 1 to 10 with increase in temperature, in accordance with the duration of exposure.

3. A proposal is made concerning the possibility of formation of aspartic acid through carboxylation of β-alanine, connected with the chlorophyll-protein complex which is an acceptor of carbon dioxide in the process of photosynthesis.

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THE ROLE OF NUCLEIC ACIDS IN THE PROCESSES OF GROWTH AND BUD DORMANCY OF FRUIT CROPS

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The omnipresent distribution of nucleic acids in the organic world, as well as their concentration in locations of the greatest activity of physiological processes, in embryonic and specialized tissues, indicates that they play a very important role in metabolism.

The active role of nucleic acids and their components has been shown in growth and morphological processes [1-8], as well as in the processes of wound healing and the graft union [6, 9]. Intensification of the synthetic activity of the cell is indestructably bound with the accumulation of nucleic acids in the cell [10, 11].

Recently, utilizing the method of labeled atoms, the participation of nucleic acids in protein synthesis [12] and their accumulation in embryonic tissues [13] were confirmed.

Nucleic acid content changes considerably, not only with the age of the tissue, but also with the conditions of plant growth (light, nutrition). Here, one notes a greater mobility of RNA, as compared with DNA [1, 2, 5, 14, 15].

As is known, the state of dormancy and frost resistance of fruit crops under the conditions of the middle belt of the USSR is a very pressing problem. The studies have been carried out to clarify various aspects and characteristics of this state [16-19]. However, up to the present time, the behavior of nucleic acids in dormant tissues and their dynamics in the annual cycle of woody plants have not been sufficiently investigated. The data available on this question are very limited [18, 20, 21, 22].

Our problem was the cytophysiological study of the nucleic acid content of apple and cherry buds in the course of their annual cycle, from the moment of their initiation, through dormancy until opening of the buds in the spring. We believed it would be interesting to clarify the dependence of nucleic acid content of buds on growth, on the degree of their differentiation, on the state of dormancy and frost resistance, and also on weather conditions.

METHODS

The buds of frost-resistant Chinese apple and two varieties of cherry—frost-resistant Polevka, and weakly frost-resistant Lyubskaya—were used for investigation.

Freshly collected buds, freed from external scales, were fixed in Helly and Carnoy fluid. Fixation was carried out every 5-10-15 days from July until October, once a month from November until March, and four times during April until the opening of the buds. After the usual microtechnical processing, the preparations were stained with Feulgen's basic fuchsin (Schiff reagent) for detection of DNA, and with Unna's methyl green-pyronin for detection of RNA in the tissues. For preparation of methyl green-pyronin we used a methyl green which was previously purified from any possible admixture of methyl violet [23].

Staining for detection of DNA and RNA was done along with control slides. In individual cases, the preparations were stained with Heidenhain's iron hematoxylin. In this work, we used mainly the material of 1956/57 and partly, that of 1955/56.

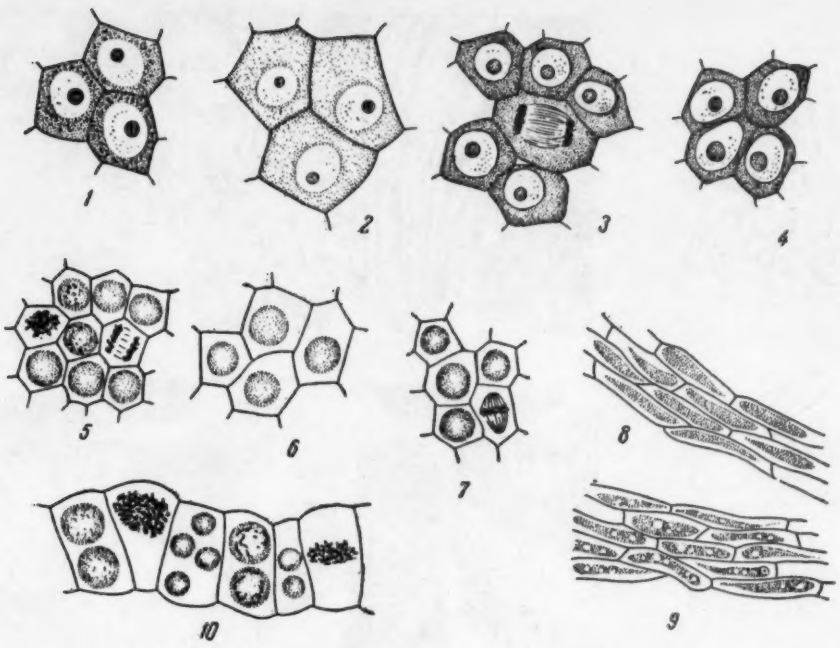

Fig. 1. Dynamics of nucleic acids in fruit tree buds. 1-4) Reaction for RNA; 5-10) reaction for DNA; 1, 5) growing point of a bud, July; 2, 6) part of the flower primordium, January; 3, 7) part of a flower primordium, April; 4) archesporium of anther primordium, January; 8) bud procambium, January; 9) bud procambium, April; 10) cells of tapetum, April

The degree of bud differentiation and growth was determined from permanent preparations from the rate of cell division and the state of dormancy from the characteristic dormancy signs [16, 6], as well as from the absence of cell division. The DNA and RNA content was determined cytochemically in the tissues.

RESULTS

Nucleic acids in the buds of fruit trees (apple, cherry) are mainly concentrated in the meristems of the protuberances of flower primordia, and in the first leaflets covering it; there are rather large concentrations of nucleic acids in procambial tissue, and very little, or none at all, in the covering scales and in the underlying tissue of buds.

In July, the buds are very small, and represent undifferentiated growing points, covered with leaf primordia and scales; their underlying tissue consists of large-celled thick-walled parenchyma; the growing point and the leaf primordia are composed of typical small-celled merstematic tissue (Fig. 2, 2). At this time frequent cell divisions are noted in various mitotic phases in the meristem, and active growth of buds occurs, with an increase in bud size. The RNA content in meristems is significant, while in the other parts of the bud it is very low or is altogether absent; on the other hand the DNA reaction is of medium intensity, while in parenchyma cells the reaction is negative (Fig. 1, 1, 5). As the bud grows, the meristems of the growing point moves closer to the periphery, while at the same time its internal and lower parts are filled with large-celled tissue. Correspondingly, RNA and DNA in general are localized in the peripheral parts of the undifferentiated growing point, gradually decreasing toward its inner parts. In the beginning of August, a hardly noticeable differentiation of buds begins; the tip of the growing point becomes flatter, and the protuberances of flower primordia begin to appear on it. When the protuberances appear, the greater number of mitoses is concentrated within them (Fig. 2, 1). The moment should be particularly emphasized, since there are data which indicate the absence of the mitotic type of cell division in growing points during differentiation of flower primordia [24]. Growth and differentiation

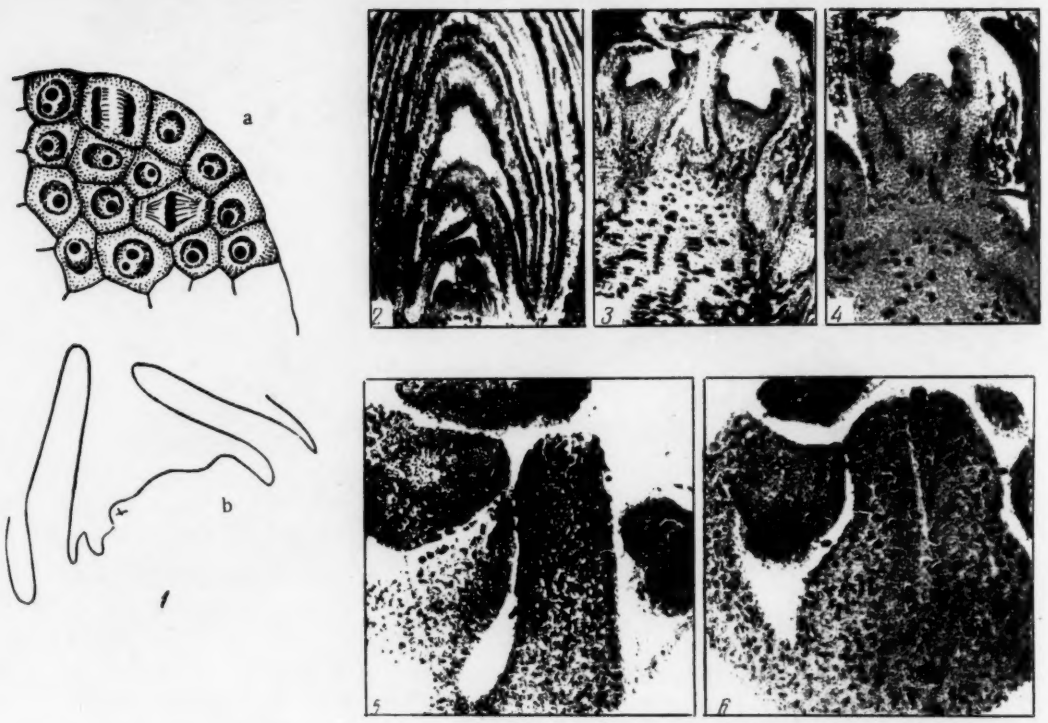

Fig. 2. Dynamics of bud formation in cherry. 1) Initiation of flower protuberances, August; b) outline drawing, a) part of tissue, indicated on the outline by a cross(×), mitotic divisions are visible; 2) bud growing point, July; 3) bud flower primordia, August; 4) bud flower primordia, September; 5, 6) primordia of pistil and anthers, in which initiation of the first archesporium can be seen, October; 5) cherry variety Lyubskaya; 6) cherry variety Polevka

of buds occurs very intensively during August. In the end of the month, 2-4 flower primordia can already be observed in the buds (Fig. 2, 3). The protuberances, which rapidly increase in size, differentiate, developing primordia of pistil and stamens. An intense RNA reaction is noted in all meristems of flower primordia; it is concentrated in the protoplasm and nucleoli.

It is known that with increase of RNA concentration in tissues, there is also an increase in either the size of nucleoli, or their number in the nucleus [1, 2, 6b, 9b, 10, 19b, 20].

In protuberances of the primordia of pistils and stamens, which are richest in RNA, we observed either 1-2 large nucleoli, or 3-4 small ones in the nuclei. The RNA content is very low in the other tissues of flower primordium; it is concentrated in small amounts in the protoplasm around the nucleus, and in the very small, almost disappearing nucleoli. The RNA reaction in the underlying tissue is either very weak, or negative. A strong reaction is noted in the procambial tissue of buds. The DNA reaction in meristems of flower primordia is of medium intensity; it is greater in the growing points of protuberances and less in other parts. In the bud scales and in the underlying tissue the DNA reaction is either very weak of negative.

The degree of differentiation of flower primordia toward the end of August is the same in both varieties of cherry and in the apple. In September, a certain increase in flower primordia of buds was observed, due to continuing cell divisions (Fig. 2, 4). It should be noted that the number of mitoses at this time is noticeably decreased from 8 to 10 per section, as was observed in August, to sporadic individual mitoses in September; however, in some samples, particularly from warm days, spurts of mitoses were observed in the tissues.

This very much retarded growth, with a decreased rate of cell division, still leads to further differentiation of flower buds. In cherries, the initiation of young pistils occur, and a primary archesporium is initiated in anther primordia (Fig. 2, 5, 6). Differentiation of flower primordia in the apple takes place more slowly; the appearance of pistil primordia may be observed in individual buds. As a rule, the flower primordia of apple winter in the state of a homogeneous meristem.

Together with retardation of growth processes, the nucleic acid content gradually decreases. In October the DNA reaction is lower than medium intensity in many cases, and the RNA content is also considerably decreased. An intensive reaction is noted only in small parts of the meristem, where mitoses occur. The archesporial tissue of anthers is characterized by a high RNA content, both in the cytoplasm and the nucleoli (Fig. 1, 4). There is an indication that the high nucleic acid content of nongrowing tissues should be regarded as an important storage of energy for the future [6a]. One should, evidently, regard the high basophily of archesporial tissue from this point of view. DNA content in the primary archesporium is very low. The level of nucleic in flower primordia considerably increases on certain, warmer, days, an increase which is accompanied by a certain activity of cell division.

In the middle of December mitoses were not observed as a rule; individual ones sometimes occurred. The rate of nuclear reactions at this time is rather low; only the primary archesporium retained a high RNA content–January of 1957 was warm; the air temperature was 3° on January 11—the day samples were taken. At this time individual mitoses were observed in flower primordia in cherries. In the buds of the varieties studied, fixed in February, there were no mitoses, and both DNA and RNA reactions were of medium intensity (Fig. 1, 2, 6, 8).

In the buds of cherries, and considerably more seldom in apple, separate segments of necrotic tissue were occasionally observed, which evidently were a consequence of too sharp temperature variations, both in the course of the day and in the course of the winter. Necrotic tissues are distinguished by a high degree of pyknosis.

In March, a certain increase in tissue activity was noticed; the nucleic acid content was slightly increased and many mitotic divisions began to appear. In the beginning of April, many mitoses were noted in cherry meristems, and the DNA reaction was of medium intensity. RNA occurred in large amounts in the archesporium of anthers, and in meristems of flower primordia, while there was very little RNA in underlying tissues (Fig. 1, 3, 7, 9). In the middle of April, the DNA content in buds was noticeably increased; a particularly large amount was found in the forming ovule and in the stigma of the young pistil, where frequent mitoses in different forms were observed; fewer mitotic divisions were found in anthers, and they are almost absent in other meristematic tissues. In apple flower primordia, the DNA content also increased with a simultaneous increase in cell division activity. In the course of April, particularly in the end of the month, with a rather high level of nucleic acid content in tissues, active growth processes took place in flower primordia of apple and cherries. Bud differentiation, interrupted by winter dormancy, was continued. In apple, the primary archesporium of anthers appeared in the end of April, but ovules appeared only in the beginning of May. In cherry anthers, the nutrient tissue of pollen — the tapetum — was formed, which had a very high content of both DNA and RNA; it grew rapidly because of mitotic and nonmitotic divisions of the nucleus, forming two- and four-nucleate cells (Fig. 1, 10).

In the archesporium, the reduction division of the pollen mother cells took place. The pistil grew rapidly, forming a long style and stigma, and many mitotic divisions were found there in various phases. DNA and RNA were concentrated in considerable amounts mainly in the tissues of the stigma, in the conducting tissue of the pistil, and in the ovule, where the integuments were already being initiated, and the archesporal cell began to appear. The underlying tissue of buds contained insignificant amounts of nucleic acids.

DISCUSSION

While studying the dynamics of nucleic acids in the annual cycle of buds in woody varieties in relation to the degree of their frost resistance, growth, and differentiation, as well as weather conditions, we have established that the content of nucleic acids in buds of fruit trees changes in the course of the annual cycle: it is decreased with cessation of growth and transfer of buds into the state of dormancy and is noticeably increased with resumption of growth processes. These regularities we provisionally call the seasonal dynamics of nucleic acids. It indicates the great role of nucleic acids in growth and morphological processes.

The seasonal dynamics of nucleic acids, in all probability, was laid down in the process of evolution, as was the whole metabolism of woody plants, which must pass into a state of dormancy during the season unsuitable

for their growth. In the process of evolution, the state of dormancy during low temperature became a necessary condition for the normal growth and development of the majority of woody varieties in temperate latitudes. A decrease in the activity of physiological processes during dormancy, a certain slacking up of living activity in tissues accompanies the breaking of dormancy, and, further, the beginning of growth processes.

In anaylzing the experimental material, it is necessary to emphasize that nucleic acids are distinguished by a great mobility: their content changes not only within the limits of the individual large steps of the annual cycle, but also, under certain conditions, within the limits of short time intervals. The great mobility of nucleic acids has been shown in bacteria [25], as well as in the process of karyokinesis [6a, 26].

Comparing the data obtained with the weather conditions during 1956/57, we can come to some conclusions concerning the dependence of nucleic acid content in buds on weather conditions, and mainly upon the variations in air temperature.

From investigations of dormancy in woody varieties, it is known that summer-fall conditions — mostly, nutrition, moisture, and temperature — place a certain imprint on the state of dormancy and, consequently, on the frost-resistance of woody varieties [19a, 27]. Plants which are well prepared for winter are in deep dormancy and, because of that, are more frost resistant; their cells react less to the changes in external conditions during autumn and winter. During unfavorable summer-autumn conditions, when plants are poorly prepared for the winter, tissues go into a dormancy state which is not very deep, and easily come out of this state even during a short-time thaw; the following frosts then kill tissues, organs, and in some cases even the whole plants. Buds of woody plants which are poorly prepared for dormancy react particularly sensitively to changing external conditions, and particularly to a change in temperature. With warming weather, the synthetic activity of individual groups of meristematic cells is activated, their nucleic acid content, particularly that of RNA, increases, and cell divisions begin to occur. Using the material of 1956/57, we found the same phenomenon. Fruit trees in 1956/57 turned out to be poorly prepared for dormancy and were especially sensitive to variations in air temperature; on the background of the generally low level of nucleic acids an increase in their content was noticed at individual periods, and this increase was found in those segments of meristems where mitotic divisions were simultaneously found. On comparing this phenomenon with air temperature during the day of sampling, we came to the conclusion concerning the dependence of nucleic acid content in weakly dormant tissues on external conditions, in particular on air temperature. This relationship emphasizes the considerable lability of nucleic acids, particularly of RNA.

Variations in nucleic acid content in buds of fruit varieties in the course of short intervals of time which are connected with changes in external conditions (such as temperature), we provisionally called the weather dynamics of nucleic acids.

Thus, on the background of the seasonal dynamics of nucleic acids in buds of cherry and apple in the course of annual cycle, when the basic regularity of change in nucleic acid content is clearly seen in tissues, the weather dynamics of nucleic acids can be noted, which depends on sharply changing external conditions.

During the years with more favorable conditions for preparing plants for dormancy, as well as wintering, the basic seasonal dynamics of nucleic acids is particularly noticeable. The data of a study of nucleic acid metabolism in woody varieties, carried out by T. P. Petrovskaya [18b] support this. Actually, the conditions of preparations for dormancy and wintering during the period of this work in 1950/51 were most favorable; the plants were in deep dormancy and, possibly because of that, no weather dynamics of nucleic acids was found. At the same time, the regularities of the main course of nucleic acid metabolism in buds was confirmed in its general features. Our experimental material has shown that DNA content changes considerably less in the course of the whole annual cycle in buds than does that of the more labile RNA.

As has been shown, the procambial tissue of buds is characterized by a high nucleic acid content. It is composed of several rows of thin-walled long cells, the thick cytoplasm of which, together with numerous nucleoli, is enriched with RNA; the nuclei are unusually long, often spindle-shaped, with a high DNA content (Fig. 1, 8, 9). A high degree of basophily was also shown in the procambium of rootlets in willow, apple, and grasses [62].

The morphological role of nucleic acids, in particular after formation of vascular bundles, has been noted in the papers of Konarev [2]. However, the large content of nucleic acids in procambium may be explained not only by the meristematic nature of the tissue; here, the role of nucleic acids may not be limited only to its morphological significance.

It is known that, aside from embryonic tissues, the nucleic acids are concentrated also in the most active tissues (glandular tissues, etc.) [5, 6a, 11]. It was also shown that vascular bundles of higher plants also show a high physiological activity [9, 28].

Sufficiently high physiological activity is also present in the procambial tissues of buds — undifferentiated vascular paths, which supply the embryonic tissues of buds with water and necessary plastic materials. With the onset of dormancy, when the physiological activity of cells falls to a minimum, the nucleic acid content in the procambium falls, particularly that of RNA; with the breaking of dormancy, their content increases.

During examination of experimental material, we have repeatedly observed separate necrotic segments in the tissues of buds, which are sharply distinguished from healthy tissues by the contraction of the cell protoplasm to various degrees, by smaller, compact nuclei, and above all, by an intensive DNA and RNA reaction.

Increased pyknosis of injured tissues, particularly in the first stages during paranecrosis, has been noted by a number of authors [6b, 15, 29]. Evidently, it may agree with a suggestion of Trifonova [29], who regards increased pyknosis during paranecrosis as a defense reaction of organism, during which protein synthesis is activated, making up for a protein deficiency in cells, caused by the injury.

In conclusion, we should point out the necessity, for the solution of some questions in physiology, of a combination of data from biochemical analysis with cytophysiological data, since biochemical analysis of an in toto structure may lead to an incorrect judgement concerning the localization and accumulation of nucleic acids in buds, in the course of the annual cycle (from the moment of their initiation to their opening) [21].

SUMMARY

The nucleic acid content of fruit plant buds decreases when the plant goes over to the dormant state and increases upon breaking of dormancy. This is the so-called seasonal dynamics of nucleic acids. The latter is especially pronounced in plants which are in a state of profound dormancy. In a general way it also occurs in plants which are not very well adapted to the dormant condition. In those years when the weather was unfavorable a so-called weather dynamics of nucleic acids which is related to changes in the environment (mainly air temperature) during a short time period was found to be super imposed on the seasonal nucleic acid variation.

The large content of nucleic acids (DNA and RNA) in the procambium is an indication of the high physiological activity of the nondifferentiated conducting channels. Increase of the amount of nucleic acids in tissues points to the protective role of nucleic acids; the latter promote synthesis of proteins which subsequently make up for the loss of proteins caused by injury.

Compared to cherry buds those of the apple tree winter in a less differentiated state and bloom later in the spring, the result being a higher degree of cold resistance.

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SEVERAL QUESTIONS ABOUT THE PHYSIOLOGY OF THE MINERAL NUTRITION OF PLANTS

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An important place in the study of the mineral nutrition of plants is occupied by the question of the role of calcium, its effect in the cycle and of its ability for to be reutilized.

D. N. Pryanishnikov [1] established that insufficient calcium retards the mobilization of reserve carbohydrates and proteins in sprouting seeds, and this results in the death of the shoots. In the later stages of development of higher plants, calcium is absolutely necessary for the correct course of the processes of carbohydrate and nitrogen metabolism. There are indications that calcium takes part actively in the processes of the division of cells; this is apparently connected with the fact that calcium enters into the composition of the middle lamella. Calcium is needed by the higher plants for the formation of oxalate, in other words, for rendering harmless oxalic acid; earlier this was viewed as the basic function of calcium, but actually this is far from true.

Calcium, being a colloid-activated cation, has a very important significance for the creation and maintenance of the normal status of biocolloids and the normal structure of the living composite parts of the cell protoplasm, such as the nuclei and plastids. It follows from this that the metabolism in the broad physiological-biochemical idea such as was explained by F. Engels is connected with calcium. Insofar as calcium in this case determines the structure of the living substances, it is clear that it affects it different characteristics, in particular the permeability of the protoplasm [2]. We must state from Genkel's works [3 and others] that calcium in changing the characteristics such as viscosity, elasticity, water supply, etc. of biocolloids, must affect such features of primary importance in plants as drought resistance, heat resistance, and also salt resistance [4].

Calcium is an antagonist of sodium, as a result of which salt resistance of plants on weakly saline soils and on solonetz increases when calcium is added to these soils by means of their gypsum [5].

Calcium is also an antagonist of another element necessary for life, magnesium. The universal role of calcium in the creation of a physiological equilibrium is generally stressed in the literature.

The many-sided share of calcium in the complex life processes can be considered as definite. This, it appears, is concerned with the fact that calcium is found in plants in an active state and that it is mobilized. However, authors adhered to and adhere to an opposite point of view. Thus, Sabinin [6] gives the elements of mineral nutrition as taking part or not taking part in the cycle. This division, according to his view, concurs with the division into elements subjected or not subjected to repeated use, that is, reutilized; in the latter group the author places Ca, Fe, Mn, B, and Zn.

D. A. Sabinin considers as a reason for the mobilization of calcium the different solubility and chemical resistance of oxalate, which makes up, according to his idea, a significant part of the entire reserve of calcium in the plant. It is not possible to recognize these considerations of D. A. Sabinin as fully conclusive. Thus, Tueva [7] shows in his work that with a pH less than 6.0, calcium is given off from the roots of grasses grown in a water culture. Ratner [8] established in a number of his interesting works that a significant part of the potassium and calcium in plants can be given off from them for a short time in conditions of a transpiration flow of sufficient rapidity. If this is so, then there is no doubt that conditions can be created in plants in which calcium will be reutilized.

D. A. Sabinin [6] emphasized that calcium has an acropetal coefficient of concentration. In this he relied on the work of Cowell [9] with the leaves of cabbage. Cowell's data do not have a broad significance from our point of view. D. A. Sabinin himself thought the data of a similar sort scarce and of a random character.

In order to resolve the questions listed above: 1) can calcium be reutilized or not, 2) is its coefficient of concentration acropetal or basipetal, and 3) how it enters into the plant through the leaves, it is natural and necessary to use the method of tracer atoms because other methods have not given clear answers to the indicated questions up to this time. Meanwhile, these questions have broad theorectical and practical significance. Of course, obtaining a reliable answer to the indicated questions by the radioactive isotope method msut take thought.

I. V. Mosolov and his co-workers [10] did not discover reutilization of calcium (Ca^{45}) in their first work with the leaves of clover and tobacco. Some was obtained in later experiments with clover and tobacco where the same authors, in contrast to the earilier conclusion, recongnized that calcium can undergo reutilization to some degree. In experiments in which Ca^{45} was placed on the leaves of different stages for sunflower, tobacco and tomato plants, the authors thought that the radioactive isotope did not move into the other leaves. However, in an analagous experiment with corn, an insignificant movement of Ca^{45} from the treated leaf into lower leaves was noted. In one of the experiments of I. V. Mosolov and his co-workers, in which Ca^{45} was introduced into the soil under the roots of different plants, the Ca^{45} was later found in all organs of the plants and the highest radioactivity was noted in the upper young leaves.

A. V. Peterburgskii established in experiments with winter rye, oats and peas in isolated cultures that Ca^{45} moves from one portion of the roots into another only to an extremely weak degree.

The material on the reutilization of calcium that was noted in the report by T'yuki and co-authors at the Geneva Conference is worthy of attention. The authors, on the basis of experiments with a number of plants, came to the conclusion that Ca, Sr, and Ba are not transferred from the parts into which they entered; therefore their movement in a downward direction is absent. They were also able to verify this position in an experiment with strawberry. However, the radioautograph that they gave shows differently. After the Ca^{45} was absorbed by the roots of the central plant, the radioactive isotope: 1) spread not only in the younger plants, but also in the older plant; 2) moved from the leaves of young plants, in which Ca^{45} had accumulated, into the roots, that is, in a downward direction. Thus, the reutilization of calcium is again indicated.

Among the investigations with Ca^{45} the work of Abutalybov [11, 12] is the most interesting. In 1955, in the first experiment with cotton and rose, the author came to the conclusion that the processes for reutilization of calcium were present in the growing organism. At the same time, according to M. G. Abutalybov's idea, there takes place a continuous conversion of the active compounds of calcium into passive forms, which are stored in the lower parts of the plants and cease to take part in the cycle and repeated use of calcium. M. G. Abutalybov's experiments with cotton, rose, peach, quince and lilac, carried out with the use of the tracer-atom method, showed that Ca^{45} moves both in an upward and in a downward direction. This can be viewed as a manifestation of the capacity of calcium for reutilization. In another work, Abutalybov [12] approached the study of the very important question of the distribution of calcium in plants. He proposed to differentiate three forms of calcium compounds: 1) water soluble, 2) adsorbed, and 3) acid soluble. The first two forms of compounds have a basipetal gradient of concentration in plants; the gradient of concentration for the acid-soluble forms is acropetal. We think that the first two forms of the calcium compounds can be considered physiologically active and relatively mobile, and this makes them reutilizable; the third form is obviously physiologically passive and nonmobile.

On the basis of the indicated experiments with Ca^{45}, it is possible to assume that on the whole the reutilization of calcium for plants takes place to a greater or lesser degree under specific conditions. Expanded and deeper investigations with Ca^{45} on different plants are needed for the final solution of the question. The coefficient of concentration of calcium can be acropetal and basipetal and that is very important for the correct understanding of the calcium cycle in plants.

The second important question of plant nutrition is the question of foliar feeding. It is unnecessary to prove this here, considering the great amount of literature on the question of foliar feeding which has appeared in recent years (Soviet and foreign). We will only note that the book by Avdonin [13], published as a help to the working agronomist, has a separate chapter, "Foliar feeding".

Agronomists view foliar feeding as a new technical agriculture method tested on many crop plants. This is correct, but foliar feeding cannot be approached simply and only from the side of technical agriculture. Foliar feeding has a broad physiological significance.

Foliar feeding, that is the spraying of the aerial organs of plants with solutions of nutrient substances, results in the acceleration of the growth and development of plants, increases the quality of the production, decreases collapsing of the ovaries, and increases yields.

Zh. B. Bussengo showed the possibility for the intake of mineral substances into the leaves close to 100 years ago. However, the planned and systematic study of foliar feeding of plants was started only about 20 years ago by Matskov and his students [14]. For the past 20 years many investigators have done much in the area of foliar feeding in the Soviet Union [15-18 and others]. The method of foliar feeding is not only studied, but it is used in different parts of the USSR on a large scale (in Uzbekistan, the Ukraine, Kuban', etc.). Aerial spraying of cotton, sugar beets, and other crops is carried out.

However, positive results to the desired degree are not always obtained with foliar feeding. This is obviously a result of the fact that the method itself has been inadequately studied. Actually a whole series of questions connected with foliar feeding demand urgent solution. We will touch only on the more important ones.

Nutrient solutions of a different composition are proposed for feeding; most often this solution is made of superphosphate, a solution of NH_4NO_3 and potassium salts separately or in specific combination and in various concentrations. In the USA, synthetic urea is widely used as a source of nitrogen in foliar feeding. An important role in foliar feeding is played by trace elements (B, Mn, Zn and others) with which the experiments of Vlasyuk and his co-workers [16], Yakovleva [19] and other authors are concerned. It is necessary to note particularly the positive effect of boron compounds on the seeding of perennial grasses and on fruit crops * With foliar feeding, the trace elements can be applied in combination with the macroelements, or separately.

It is completely possible that the one-sided use of activating solutions of simple composition decrease the effectiveness of foliar feeding. The experiments of Kalinkevich [20] on the foliar feeding of buckwheat with a solution of $(NH_4)_2SO_4$ separately and in combination with calcium monophosphate shows this. Obviously the solutions used in foliar feeding must be to a greater or lesser degree physiologically counterbalanced. However, an excessive complication of the composition of the solution (as given, for example, by T. N. Godnev and his colleagues) is presented as unsuitable. It is necessary to consider the active reaction of the solutions which are being prepared for foliar feeding.

The available data show that double neutralized superphosphate, which is easily soluble in water and which gives a less acid solution than the normal superphosphate, must be used as much as possible in foliar feeding. Potassium-ammonium-phosphate (a new nonchlorine fertilizer) can be considered as very possible, it appears, for foliar feeding.

The concentration of the nutrient solution for foliar feeding does not have to be high. In experiments carried out in Saratov, we used solutions with concentrations of 1.5-2.0% with success. According to Mednis data [21], even 30% solutions could be used without risk of burning the plants in the Yaroslav region with foliar application from an airplane, because of the strong dispersion of the liquid. However, according to the same data, even a 10% solution of this same composition caused burning to the leaves with ground spraying.

When carrying out foliar feeding, it is necessary to consider not only the composition and concentration of the solution, but also the volume of liquid applied to a unit of area on one fruit tree, etc. A model form for the composition of solutions for foliar application, without considering the biological characteristics of plants and the differences in soil-climate conditions, can give very negative results.

We will give such an example. Mednis, for feeding of plum during the flowering phase (fruiting plum), applied a 4% solution of a mixture consisting of 7 kg NH_4NO_3, 10 kg of superphosphate, and 1 kg KCl. According to Ya. A. Mednis data, who worked in the Yaroslav region, this solution gave positive results. In the conditons of the Saratov region, the Mednis solution appeared to be completely ineffective for foliar feeding of fruit trees because it not only burned young leaves and flowers, but strongly damaged even the skin of young apples. A sharp difference in the action of the Mednis solution on fruits in the Yaroslav and Saratov regions obviously is a result of the great difference in climate in the indicated regions. I suggested three nutrient solutions

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* We are not discussing here the physiological nature of the action of boron on plants.

(K_1, K_2 and K_3), differing in their composition and active reaction of the medium, for the Saratov region: K_1– superphosphate (5.0%), NH_4NO_3 (0.25%), KCl (0.2%), H_3BO_3 (0.05%) (it must be noted that less than $\frac{1}{5}$ of the superphosphate is dissolved in the solution); K_2– K_2HPO_4 (1.0%), $NaHCO_3$ (1.0%), $Na_2B_4O_7$ (0.05%); K_3– K_2HPO_4 (1.0%); NH_4HCO_3 (1.0%), $Na_2B_4O_7$ (0.05%).

All three of the solutions increased the yield of fruiting plants (corn, cucumbers, tomatoes, cabbage, apple, cherry, and plum), but to different degrees.

Matskov [22] also showed the dissimilar response of various plants to foliar feeding. This is also confirmed by our data obtained in 1955 and 1956 for the Saratov region. It is most essential that the effect from spraying some of the same crops in different years was not the same. Near Saratov in 1955, which was a hot and dry year, foliar feedings on all crops acted more positively than in 1956 when there was much moisture and the temperatures were high. This fact has a good deal of interest because in the Southeast (and generally in places with a dry climate), greater results can obviously be expected from foliar feeding than in regions with a temperate climate and a significant amount of rainfall.

Of course foliar feeding cannot be viewed as being independent of other factors. Soil nutrition is basic, but foliar feeding can substantially supplement it and even correct in strength the specificity of its action on the growing organism. The effectiveness of foliar feeding, without a doubt, is connected with the fertility of the soil.

Therefore, it is necessary to study the action of foliar feeding parallel with the action of normal root feeding and generally with the action of fertilizers. Precisely because of this, microbiologists, agronomists, and soils experts must take part in works with foliar feeding as well as physiologists, biochemists, and biophysicists.

In connection with the question of the rate of assimilation of Ca^{45} in the leaves and its distribution on the plants, we considered it expedient to carry out foliar feeding of $CaCl_2$ on solonetz soils in the conditions of western Siberia in an experimental manner (in cooperation with soil experts) with the goal of increasing the salt resistance of various crop plants.

Foliar feeding of vegetable crops under conditions of enclosed ground is of special interest. There are very few Soviet works (for example, Oganov [23]) in this direction. This same question concerned Boynton [24] in his survey article. Plants on enclosed ground react very positively to foliar feeding, in agreement with the indicated data in the literature.

The use of the aforementioned solutions K_1-K_3 that we made in a Soviet greenhouse combine for spraying of tomatoes, on the greenhouse in the spring-summer months of 1956 gave an increase in the yield up to 28%.

Two experiments were carried out by colleagues in the Section of Physiology, Biochemistry and Biophysics of Plants ZSFAN in the commercial conditions of the Novosibirsk greenhouse-hotbeds combine (on an area of 1200 square meters) with foliar feeding of tomatoes from the middle of October, 1956, to February, 1957. Foliar feeding gave an increase in the yield of the fruits of tomatoes in the various experimental variants of 15 - 25%. These figures, which are not the maximum possible, show that the possibilities for foliar feeding of vegetable crops in the autumn-winter months are very bright in western Siberia.

Corresponding to this new data, the substances held in the nutrient solution placed on the leaf first enter into the leaf tissues through the stoma and then the intake of substances through the cuticle is added to this process. For mesophytes, to which group most crop plants belong, the stoma as a rule are found more on the lower surface of the leaf than on the top; there are no stoma on the upper surface of the leaves for a number plants, for example, apple, and citrus plants. Therefore, water solutions of substances at first move significantly faster through the lower epidermis, but after a while when the substances begin to enter through the cuticle, the difference in the rate of assimilation of substances through the upper and lower surfaces of the leaves gradually decreases and is leveled out. Several foreign authors (Cook and Boynton [25 and others]) showed such a picture of the assimilation of soluble substances into the leaves. These data find support in the investigations of my student, L. A. Vetchinkina, who in working with P^{32} in various plants (corn, cucumber, potato, etc.) discovered a more rapid intake through the lower surface of the leaf.

In accordance with the information given above, it would be better to spray the leaves on their lower surfaces whenever possible. However, this method of spraying leaves from below is not compulsory.

The method of foliar feeding made it possible to show that the various substances themselves applied in solution form on the surface of the leaves can penetrate into the leaf tissue (Kaindl [26]). The method of foliar feeding also makes it possible to discriminate in the mechanism of the assimilation of nutrient substances from the solution into the leaves. The data of Matskov and Farfel' [14] are concerned with this question. These authors studied the penetration into the leaves of K and PO_4 from solutions of KCl and KH_2PO_4 in concentrations of 0.1 and 0.5 with different reactive medium. The quantity of the substances which penetrated into the leaf was determined by the decrease in their concentration in the solutions in which the leaves were submerged. According to the authors' data, potassium entered faster than phosphorus; here, the rate of assimilation of K and PO_4 depended on the size of the pH of the solution. The duration of the stay of leaves in the solution varied from 0.5 to 24 hours (the analyses were carried out after 0.5, 1.5, 3.0, 6.0 and 24 hours). F. F. Matskov and R. L. Farfel' came to the conclusion that the quantity of potassium and phosphorus extracted by the leaves does not depend on the time of its stay in the solution (if the observations are carried out over a period of 24 hours). According to the authors, this indicates the fact that the mechanism of absorption of nutrient substances from the solution with which the growing tissues come in contact is similar for the root and leaf because the basis of this mechanism is adsorption which, as we know, takes place at a very high rate. These ideas were accepted unconditionally by Yakushkin [15], Pinevich [27] and others, and the understanding of the mechanism of the assimilation of nutrient substances into the leaves in foliar feeding is based on them.

The position concerned with the dissimilar rate of assimilation of K and PO_4 can be accepted with the reservation that it has significance for one side or the other depending on the size of the pH. However, the conclusion of the authors that the assimilation of K and PO_4 into the leaves does not depend on time is not presented as basic. The method of carrying out the experiments brings up these objections.

First, the leaves that were separated from the plants were immersed in one or another solution and held for whole days in this completely abnormal situation. The physiological and biochemical processes in the leaves were undoubtedly altered by such a long duration under water, that is, in conditions of clearly inadequate aeration, and could have proceeded up to the formation in the surrounding solution of the substances already adsorbed by the leaves.

Second, the mechanism of the assimilation of nutrient substances must not be studied in leaves separated from the plants. The completeness of the growing organism must not be forgotten, as Sabinin also noted [6]. The adsorption of nutrient substances is only the first stage of their assimilation into plants and growing cells. The further assimilation of these or other substances depends on the rate of their inclusion in the normal metabolism and on the rate of their distribution and use by the given organs and plants as a whole. The process of adsorption is a physical-chemical process, while the assimilation of substances is a complex physiological process. If one doesn't want to fall into an error, he must consider this position.

Third, the method used by the authors does not have anything in common with the method of foliar feeding and, therefore, it would be incorrect to base a hypothesis of the mechanism of the assimilation of various substances into the leaves for foliar feeding on the experiment of F. F. Matskov and R. L. Farfel'.

It is necessary to approach a solution of this question on which F. F. Matskov and his colleagues worked by using the new and most sensitive method of investigation, namely the method of tracer atoms.

In our laboratory, G. V. Barinov is carrying on work on the study of the assimilation of phosphorus into plants, and he is using the radioactive isotope P^{32} for this. The assimilation of P^{32} into the leaf cells and tissues when a solution of K_2HPO_4 is applied on the surface of the leaves of different plants is being studied.

We must acknowledge that the data obtained are in complete opposition to the results of the experiments of F. F. Matskov and R. L. Farfel'. It appears that the assimilation of phosphorus into the leaves (not separated from the plant) is in direct proportion to time. The calculation of the rate of assimilation was made by the method of measuring the impulses 5, 10, 20, 30 and 60 minutes after placing a drop of the solution $K_2HP^{32}O_4$ on the surface of the leaves. For cucumber and tomatoes, P^{32} was entering several times faster after 60 minutes than after 5 minutes. In G. V. Barinov's work, it is interesting to note that phosphorus continues to enter into the leaves even after the laps of an hour. This leads to the fact that P^{32} entered into the leaves of the plants named above many times faster after 36 hours than after 5 minutes.

It is necessary to note, apropos of this, an excerpt from Boynton's writing: "The absorption of solutions of fertilizers takes place over a longer period of time when the surface of the leaf seems dry. It is possible that the water films formed on evaporation often have a greater significance for bettering the absorption of nutrient solutions than a water solution which has been sprayed on the leaves."

The picture received here is sufficiently clear. Of course the experiments of G. V. Barinov must be considered preliminary for the present time. However, they, and the evaluation of the above, force the question of the necessity of a careful check of the data of F. F. Matskov and R. L. Farfel'.

Foliar feeding of plants in a number of cases gives a very significant increase in the yield of various crop plants: first of all, it causes large changes in the flow of various physiological and biochemical processes in the leaves (it affects photosynthesis, respiration, the carbohydrate and nitrogen metabolism, the work of enzymes, etc.); secondly, foliar feeding possesses strong and obviously independent actions. The nature of the action of foliar feeding apparently is included not only in the fact that nutrient substances move into the plant and act as usual. Obviously, these nutrient substances entering immediately into the main laboratory of plants, the green leaf, appear also to act as stimulants. The action of nutrient substances entering into the leaves during foliar feeding is rapid. Undoubtedly, foliar feeding could explain the physiological role of various macro-and micro-elements. Foliar feeding can yield much that is interesting both in the theoretical and practical sense when combined with the new methods of investigation, first of which is the tracer-atom method, and also with the method of leaf diagnostics [28]. The method of tracer atoms makes it possible to follow the physiological and biochemical processes which form metabolism. This method allows for deeper and deeper penetration into the nature of the indicated processes, which is necessary for mastering and managing them.

However, the method of tracer atoms based on ionized radiation, is by no means the only auxiliary method of investigation. One can and must speak of the use of atomic energy in peaceful goals in the correct sense of this word and as applicable to the physiology and biochemistry of plants and to agriculture.

At the present time different methods of influence are undergoing study: 1) the exposure from without of dry, soaked, and sprouting seeds; 2) soaking seeds in solutions of different exposures (natural and artificial radioactive substances); 3) foliar feeding of plants with small doses of nuclear exposures; 4) application of radioactive substances in the soil as microfertilizers. The goal of all these actions is to better the growth and development of plants and to increase their productivity.

In the Soviet Union investigations in this direction were, and are being, carried out with different plants and with different types of ionized radiation by L. P. Breslavets, P. A. Vlasyuk, N. G. Zhezhel', A. M. Kuzin, N. V. Timofeev-Resovskii and others.

The data obtained are without a doubt interesting, but at the present time, they are not identical. This profitable and important work must continue by making the investigations more precise and broadening and deepening them.

Biophysics, with its methods, is absolutely necessary for the study of plant nutrition. Biophysics is not only work with tracer elements and with ionized radiations. Work with ultrasonic methods and a number of other divisions, among them the study of the oxidizing-reducing regime of living cells, tissues, and organs of plants and animals, is included in biophysics. The oxidizing-reducing regime, on one hand, depends on the specificity of the physiological–biochemical processes and, on the other, on the flow of a number of important life processes in relation to the oxidizing–reducing regime.

We have already carrried out more than 25 years of work on the study of the oxidizing–reducing regime of plants in the Soviet Union and work has also gone on in foreign countries. In particular, my students, colleagues and I have completed a whole series of work in this direction [29, and others]. Work on the oxidizing–reducing regime of plants established no less interesting facts. For example, it has been shown that the onset of flowering and its abundance is connected with the size of the oxidizing–reducing potential. This size in plants can be changed by the action of various external factors and it depends on the internal conditions of the plants. The oxidizing–reducing regime of plants is changed under the effect of soil nutrition. This circumstance has essentially important significance for plant physiologists and soil scientists. The data obtained by P. A. Genkel' and his colleagues, who show the effect of treating the soil according to the system of T. S. Mal'tsev on the oxidizing–reducing potential of plants, are very interesting.

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BRIEF COMMUNICATIONS

THE QUESTION OF THE BIOSYNTHESIS OF NICOTINE

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The alkaloids of tobacco are the subject of many investigations, as a result of which the separate sides of the physiological and biochemical processes carried on the plants are explained. Thus, we know from experiments with irrigated tobacco plants which we and other investigators carried out that the synthesis of nicotine takes place in the roots; the new role of the activity of the roots in the synthesizing processes was also revealed in these experiments [1]. At the same time, the intake of carbon dioxide through the root system of the plants and its fixation as a result of the influence of substances in the metabolism carried out directly in the root with the following introduction of carbon into the nicotine were established [2].

Radioactivity of Plants and Nicotine

Medium into which the $NaHC^{14}O_3$ was introduced	Wet weight of plants, g	Nicotine, mg	Radioactivity	
			leaves of the upper stages, imp/min·mg	nicotine, imp/min·mg
Control (water)	19	4.2	670	285
Nitrogen—$Ca(NO_3)_2$	20	3.5	681	254
Without nitrogen (KP)	38	6.6	1118	334

There is much interest in experiments explaining the nature of the methyl radical in the N-pyrrolidine ring of nicotine. It appears that formic acid and formaldehyde, α-carbon glycolic acid β-carbon serine, α-carbon glycine, and the CH_3 group of methionine are the antecedents in the formation of the N-methyl group of nicotine [1].

The next stage is marked by investigations on the inclusion of several amino acids. Dewey and his associates [3, 4] showed that ornithine is an antecedent of the pyrrolidine ring of nicotine, and that lysine does not enter into the pyridine ring of nicotine. Dawson and his associates [5] established that nicotine acid takes part in the synthesis of the pyridine ring of nicotine and other alkaloids of tobacco.

Mothes and his associates [1] carried out a number of experiments on the foliar feeding of plants in connection with the localized synthesis of nicotine in the roots of tobacco. Thus, nitrogen was introduced through the leaves of a graft of tobacco onto a nonalkaloid plant, and also nonalkaloid leaves were rooted, leaving the root as the source of nitrogen. The spraying of leaves with a solution of ammonium nitrate did not lead to the formation of nicotine in them [1].

Nicotine increases the intake of nitrates and, possibly, their following reduction and accumulation in the cells in the form of ammonia, amides, and other forms of nitrogen, including protein nitrogen [6].

We carried out the following experiments on the question of the synthesis of nicotine in connection with the intake of nitrogen through their roots, with a further explanation of the physiology of the formation of nicotine in tobacco plants as our goal.

Plants of Nicotiana tabacum, continuously grown and kept on a Knop nutrient medium diluted to half strength, were used in the experiment according to the following scheme: water (control); nitrogen (calcium nitrate); Knop medium without nitrogen, to which $NaHC^{14}O_3$ was added in the quantity 100 μC per plant at the rate of 20 μC on each date. The volume of the nutrient medium was 100 ml. The exposure was eight days. The plants were taken up and the nicotine separated from them and precipitated in the form of dipicrate. The results are given in the Table.

The analyses of the radioactivity of the plants showed that the intake of C^{14} proceeded systematically, increasing at the end of the experiment at the same time that the radioactivity of the nutrient mixture decreased to 20 % of the original quantity; radioactivity was not discovered in the case of the experiment without nitrogen.

The plants appeared normal during the experiment and showed growth that was especially noticeable in their root system; that is, the plants did not show a reaction to the absence of nitrogen or other elements of nutrition in the nutrient medium in their external appearance.

One can see that the intake of radioactive carbon depends both on the radioactivity of the plants and on the loss from them of nicotine, because neither in the experiment without nitrogen, nor in the control (water), did the indicated medium cause any variation in the biosynthesis of nicotine.

The radioactivity of the nicotine does not depend on the intake of elements of plant nutrition through the roots. Apparently the nicotine as a secondary product of synthesis is formed as a result of the following reaction of the metabolism of those compounds which first picked up the C^{14} at the time of their primary formation.

Consequently, the absence of nitrogen in the nutrient mixture does not affect the synthesis of nicotine, which depends on the fact that the latter is formed only as a result of the active process of the active life of the plant, which takes place in the roots of tobacco themselves, and does not depend on the intake of the elements of plant nutrition.

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DYNAMICS OF THE PIGMENT COMPOSITION OF ALBINO SUNFLOWER PLANTS

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There were the following plants in a group of albino sunflowers that we investigated: 1) total albinos, and 2) albinos for which the cotyledon leaves from the first days of life were green, but for which all of the following leaves were white. The pigment composition of green sunflower plants was investigated for comparison. In addition, the change in the pigment composition of albino plants was noted in the process of their gradual greening, a phenomenon observed in the albino plants grown in containers with green sunflower plants.

All plants, both the albinos and the green plants, were grown during the autumn and winter in containers in a greenhouse where a moderate temperature was maintained, varying in the range from +5° up to +12°.

The data given are the average of measurements made on 6 to 15 plants.

The pigment composition of various parts of the green and albino sunflower plants was determined by the method of two-dimensional chromatography developed by D. L. Sapozhnikov.

In the six-day-old total albino sunflowers, only one carotene (0.31 mg%) was observed in the cotyledon leaves and the stem was completely free of pigments. We assumed that these plants could not exist in the complete absence of photosynthetic processes. However, total albinos continued very slow growth. The duration of life reached 100 to 120 days and more for many albinos in the conditions of the greenhouse with a temperature from +5° up to +10°. One pair of real leaves of small size were formed during this time and the second pair began to form. All leaves had a white color. This makes it possible to hypothesize that the photosynthetic function for total albinos in fulfilled, obviously, by the yellow pigment, carotene. This question will be the subject of our further investigations.

Three weeks from the time when the first sample was taken, we again determined the pigment composition of total albinos. A similar picture was observed in the cotyledon leaves of a 27-day-old total albino although the carotene quantity increased up to 0.54 mg%. However, now the carotene was already formed in the stem of the albino (0.42 mg%).

We can see from the data given that the total albino of sunflower does not lose the ability for the synthesis of the yellow carotene pigment in conditions of lowered temperatures, which are especially favorable for this process. As we have already noted, total albino sunflowers die after 5 to 6 days in field conditions (spring) with increased temperature, which in our conditions reached +20° and higher, and strong sunlight, but under conditions of the greenhouse with temperatures from +5° to +10°, several of them grew for a long time.

The presence of the following collection of pigments was established for albino plants which have green cotyledon leaves during the first days of their life but whose first and following pairs of real leaves are albino. Carotene (0.22 mg%), chlorophyll a (7.25 mg%) and chlorophyll b (3.90 mg%) were found in the cotyledon leaves of the albino; xanthophyll and neoxantine absolutely did not appear. Thus, the cotyledon leaves of the albino are distinguished from the green plant less by the quantitative than by the qualitative concentration of pigments. The first and second pairs of leaves of the albino contain only carotene: in the first pair, 0.15 mg%, and in the second, 0.25 mg%.

An interesting difference was observed in the pigment composition of the various parts of the stem. Carotene, chlorophyll a, chlorophyll b and pheophytin were found in the form of traces in the stem, distributed beneath the cotyledon leaves. The other part of the stem above the cotyledon leaves contained traces of carotene. Thus, all plants were divided into two groups by the collection of pigments: one yellow, containing yellow pigments and located above the cotyledon leaves, and the other green, containing green pigments, although in small quantity, and located below the cotyledon leaves. The cotyledon leaves themselves are the only parts in albino plants that have all pigments necessary, apparently, for the normal carrying out of the process of photosynthesis.

We studied the pigment composition of total albinos and albinos with green cotyledon leaves also in the process of their greening. When growing full albino plants and albinos with green cotyledon leaves in containers, we observed that the albinos began to turn green slowly in those containers in which there were green plants along with the albinos. At first the light greening of the full albinos proceeded in the stem and did not touch the cotyledon leaves. After five or six days the cotyledon leaves also began to turn green.

In the first days, that is, when the light greening was spreading in the stem, the composition of the pigments, as was expected, changed only in the stem where traces of chlorophyll a appeared at the same time that the quantity of carotene decreased to a trace. As before, only carotene was found in the cotyledon leaves (up to 0.59 mg%).

The picture of the pigment composition was as follows at the time of the light greening of the cotyledon leaves: in the cotyledon, chlorophyll a (5.19 mg%) and traces of chlorophyll b appeared; the quantity of carotene decreased slightly in comparison with nongreening cotyledon leaves of the total albino. The pigment composition did not change in the stem (traces of carotene and chlorophyll a were found). The stronger greening of the cotyledon leaves is accompanied by an increased quantity of chlorophyll b (1.38 mg%) and the quantity of carotene and chlorophyll a decrease slightly (0.27 mg% and 4.17 mg%). The pigment composition in the stem does not change. The first pair of leaves forming up to this time contain some carotene (0.25 mg%). The role of the root system in the formation of green pigment is made apparent with all evidence on the total albinos that are beginning to turn green. Thus, greening begins in the stem below the cotyledon leaves and after some time moves higher in the stem, also including the cotyledon leaves.

The albino plants with green cotyledon leaves were grown in containers with green plants and for these, as for the total albinos, a gradual greening of the real leaves was observed. The results of the investigation of pigment composition of these plants showed the following:

The light, hardly noticeable greening of the first pair of leaves (along the center vein of the leaf) is accompanied by changes in the pigment composition of the plant. There are traces of chlorophyll a in the first pair of leaves and the quantity of carotene in them decreases to a trace at the same time. In the second and third pairs of leaves, which remain albinos, the quantity of carotene decreases to a trace; however, green pigments were not found in them.

A significant decrease in the quantity both for the yellow and green pigments was observed in the cotyledon leaves at this time: carotene remains as a trace, chlorophyll a is 4.59 mg%, and chlorophyll b, 2.14 mg%. Changes were also observed in the stem of the albino both in the the qualitative and in the quantitative order. If the green pigment is found in traces only in the part of the stem that is located below the cotyledon leaves prior to the beginning of greening, then later the green pigment spreads out into all parts of the stem. We found chlorophyll a (4.30 mg%) and traces of carotene in the stem below the cotyledon leaves; carotene was not found in the stem above the cotyledon leaves, but traces of chlorophyll a and chlorophyll b did appear, and even higher in the stem, above the first pair of real leaves, there were chlorophyll a (2.15 mg%) and traces of chlorophyll b.

The formation of chlorophyll in the albinos beginning to turn green is connected with a coinciding decrease in the quantity of carotene.

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AN APPRAISAL OF THE EFFECT OF SEVERAL FACTORS IN THE TRANSPIRATION PULL OF COTTON LEAVES

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The possibility of diagnoising the dates for irrigation of agricultural crops by the transpiration pull of leaves has been established in recent years by many investigations [1]. However, the degree of the influence of such important factors as the soil mositure, temperature, and atmospheric moisture on the transpiration pull of the leaves has not been appraised to a sufficiently full degree. Meanwhile, such knowledge has principal significance both from the theoretical side of the water regime of plants and also from the practical use of this indicator in diagnosing for irrigation. In this communication we are presenting the results of two years of investigation on a study of the effect of the basic factors of the external environment on the transpiration pull of cotton leaves.

The investigations were carried out on the experimental plantings of the Ukraine Scientific Research Institute of Irrigation Agriculture (Kherson) in 1955 and 1956. Cotton in the experimental plantings presented a favorable subject for explaining the questions that interest us. The yields of cotton on the irrigated variants with two or three irrigations reached 18 to 20 centners per hectare.

The transpiration pull of the leaves was determined by the field method of Shardakov [2]. We took morphologically formed light leaves, usually the fourth from the point of growth, with six to eight typical plants in each variant. The measurements were made every five days on the two field and one nonfield variants, beginning with the budding phase. At the same time, the temperature and atmospheric moisture were measured at a level of $\frac{3}{4}$ the height of the plants with the help of an Assmann psychrometer. The soil moisture was measured every ten days in all variants in close agreement with the dates of the determinations of the transpiration pull of the leaves. The soil samples in 1955 were taken every 10 cm down to a depth of one meter, but in 1956 only to a depth of 30 cm because the soil moisture at this depth for the given soil type was practically equal to the average moisture of the calculated layer [3]. There were six repetitions of the determination of soil moisture.

The well-known changes in the transpiration pull of the cotton leaves in relation to irrigation, rainfall and soil moisture are confirmed by a normal appraisal of the results of the investigations. During the vegetation period the transpiration pull of the cotton leaves changed from six to eight atmos with ample soil moisture to 30 to 33 atmos and more in conditions of clearly expressed drought. However, the explanation of a reliable quantitative relationship between the transpiration pull of the leaves and the indicated factors of the external environment appeared to be possible only with the methods of statistical analysis. For this purpose, the factual data of measurements made at the same time were compared with each other. Only the soil moisture on the intermediate dates of measurement was interpolated with the calculation of irrigation, rainfall, and average daily consumption for each period. The correlation coefficients between the transpiration pull of the leaves on one hand, and the soil moisture, temperature, and atmospheric moisture on the other, are given in Table 1.

The highest and most stable correlation was found between the transpiration pull of the leaves and the soil moisture. We note in passing that the correlation coefficient between them was 0.86 in 1952 [4]. The effect of temperature and atmospheric moisture on the transpiration pull of the leaves was less stable, although fully reliable.

TABLE 1

Correlation Coefficients between the Transpiration Pull of Cotton Leaves (S), Soil Moisture (W), Temperature (t), Absolute (A) and Relative (F) Humidity and Saturation Deficit (D) of the Air

Factors compared	Correlation coefficients ($r \pm mr$)	
	1955	1956
S & *W*	-0.76 ± 0.081	-0.78 ± 0.054
S & *t*	$+0.27 \pm 0.116$	$+0.53 \pm 0.097$
S & *A*	-0.42 ± 0.110	-0.53 ± 0.097
S & *E*	-0.46 ± 0.105	-0.35 ± 0.120
S & *D*	-0.40 ± 0.109	$+0.63 \pm 0.082$

In Fig. 1, A the relationship between the transpiration pull of the leaves and the soil moisture is given. The curve if this relationship fits the regression equation $S = \frac{924}{W} - 2.2$ atmos where S is the transpiration pull of the leaves, in atmospheres, and W is the soil moisture, in % of field capacity.

Only in the zone of the wilting of the leaves did the transpiration pull sharply increase in a small interval for changes of the soil moisture as a result of the influence of strong atmospheric drying at the same time.

The deviation of the experimental points from the derived curve can be explained by the effect of temperature and atmospheric moisture on the transpiration pull of the leaves. We computed the correlation coefficients between the deviations of the experimentally determined values of the transpiration pull from the values computed according to the formula on one hand, and temperature, relative humidity, and the saturation deficit of the air on the other. They gave the following:

$$r_{\Delta S.\, t} = +0.37 \pm 0.118$$

$$r_{\Delta S.\, E} = -0.69 \pm 0.070$$

$$r_{\Delta S.\, D} = +0.56 \pm 0.095$$

These data indicate the reliability and stability of the effect of atmospheric moisture on the transpiration pull of the leaves. The relationship between the deviation of the transpiration pull of the leaves ΔS and the relative humidity of the air appears to be a straight line represented by the equation:

$$\Delta S = 5.45 - 0.124\, E$$

Not denying the slight effect of the air temperature on the size of the transpiration pull of the leaves, we calculated the following equation of the combined quantitative relationship:

$$\Delta S = 0.206\, t - 0.115\, E$$

The following table was constructed on the basis of this equation:

t, °C	*E*, %	ΔS, atmos	*t*, °C	*E*, %	ΔS, atmos
35	60	+0.3	35	30	+3.7
30	50	+0.4	30	40	+1.6
25	40	+0.5	25	50	−0.6
20	30	+0.6	20	60	−2.8

It is obvious that all of the various combinations of temperature and atmospheric moisture having a place in each concrete case are not covered in the given table. Nevertheless, they characterize the possible dimensions of the changes of the transpiration pull of the leaves in relation to the intensity of the annual conditions. On the basis of the latter equation, we brought in the corrections to the data of the transpiration pull of the leaves for all measurement dates. The relationship between the transpiration pull and soil moisture is given in Fig. 1, curve 1, with these corrections.

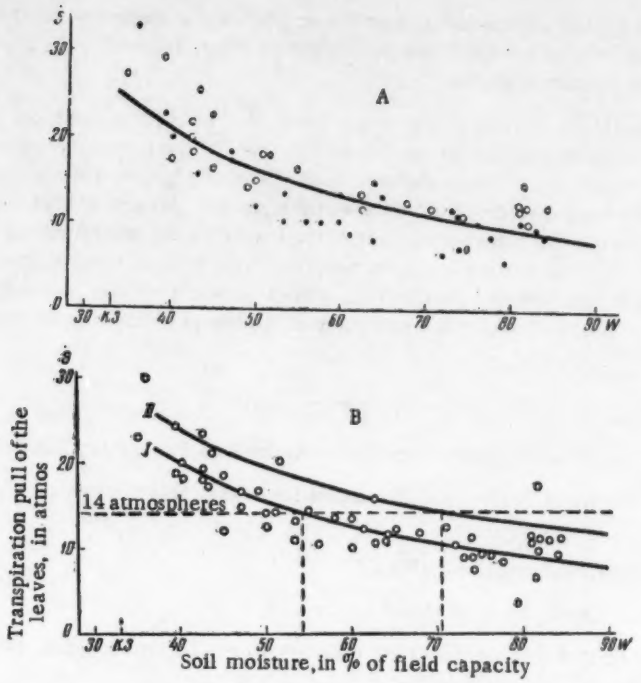

Fig. 1. The relationship between the transpiration pull of cotton leaves from 1 P.M. to 2 P.M. and the soil moisture. A) According to the data of the actual measurements (heavy points are 1955 and light ones are 1956); B) with the corrections for temperature and atmospheric moisture: I) for t = 24.6°, E = 44%; II) for t = 35°, E = 30%.

The deviations of the points from curve 1 were significantly decreased. In most of the cases, the size of the deviations does not extend beyond the limits of error of the method itself, and averages ± 1.2 atmos. The more significant deviations of some points can be explained by the influence of other factors, among them the discrepancy between the conditions of the water regime of the plants and the average moisture of the conditionally calculated layer of the soil. Curve 1 is represented by the regression equation:

$$S = \frac{864.4}{W} - 1.8 \text{ atmos}$$

for conditions of temperature and atmospheric moisture, t = 24.6° and E = 44%. Under the given conditions for the growth of cotton, the critical size of the transpiration pull, 14 atmos, corresponds to soil moisture in the calculated layer of 54% of field capacity, that is, the soil moisture below which there is a water deficit suppressing plant growth in the given conditions. For a high intensity of conditions (t = 35°, E = 30%) the relationship between the transpiration pull of the leaves and the soil moisture, corresponding to the equations given above, is given by curve II, Fig.1. The critical size of the transpiration pull of the leaves in the given case corresponds to a soil moisture for the calculated layer of 70% of field capacity; that is, this is critical for cotton moisture of a smiliar type soil as established by S. N. Ryzhov for the conditions of the Fergansk valley [5]. The fact of such a coincidence indicates the high reliability of the experimental data and the objectivity of their appraisal in accordance with the calculations given above. Besides this, the data of Fig 1, B, obviously show that the critical level of soil moisture for plants, or the moisture leading to the suppression of plant growth, is not a constant size. It depends on the intensity of the important factors of the annual conditions, temperature and atmospheric moisture, although the basic factor determining the size of the transpiration pull of the leaves is the soil moisture. This agrees with the fact that the water deficit suppressing plant growth appears at a higher

soil moisture in the hottest and driest regions and also on hot and dry days in regions with temperate annual conditions. Consequently, the level of the soil moisture critical for plants depends on the annual conditions of the given region during the vegetation period.

Without denying the possibility of an objective and reliable appraisal of the conditions of the water regime of plants by the soil moisture, we again note that the transpiration pull of the leaves is a truer and more universal physiological indicator of the conditions of the water regime of plants. By means of the transpiration pull, it is possible to objectively and accurately characterize the water regime of plants in every concrete case independent of the annual conditions. However, the transpiration pull of the leaves toward the middle of the day, with a path of the intensity of the annual conditions typical for the given area, reaches a stable level depending mainly on the soil moisture. Thanks to this, the transpiration pull of the leaves is a reliable indicator for diagnosis for cotton irrigation, just as is the concentration of the cell juice of the leaves which is in close relationship to their transpiration pull [6].

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DIAGNOSTICS OF THE REQUIREMENTS OF VEGETABLE PLANTS FOR IRRIGATION BASED ON SAP CONCENTRATION

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In 1955 we started work on the determination of the requirements of vegetable plants for irrigation based on physiological indicators. We assumed that the question of this necessity for irrigation based on the concentration of sap exuded from the leaves of vegetable plants had been adequately developed by Lobov [1-3]. Using his data, we planned to throw some light on the method and, after a check of the recommendations of M. F. Lobov, to begin to put them into production. However, the first of the tests using M. L. Lobov's method in field conditions led to complications. The sap exuded from potato leaves appeared so cloudy that the concentration could not be measured when using a field refractometer and a universal laboratory refractometer (RLU) could measure the coefficient of refraction only with decreased accuracy. Nonetheless, this was not the main reason for not using M. F. Lobov's method. Our following investigations in 1955 showed that the sap, when exuded from the leaves, carries water soluble proteins from the ruptured growing cells. The process of dissolving can be followed, measuring in succession the samples on the refractometer, for which the concentration of the sap gradually increased. Insofar as the quantity of water soluble proteins in the leaves varies and, as the experiments showed, depends on the level of nutrition, water supply and lighting, the concentration of the exuded sap always depends on its relation to the concentration of cell sap in the leaf; however, the size of this dependence fluctuates widely and it is not possible to calculate it. The method of changing the concentration of water soluble proteins in the exuded sap of the leaves by the difference between the sap concentration prior to and after boiling has been publicized by us [4]. As an example, we will give here the data that we obtained on the concentration of cell sap exuded from the leaves of tomatoes prior to and after boiling. The results were as follows:

Sap Concentration

6/4	6/10	6/13	6/17	6/21	6/24	7/1	7/2	7/11	7/15	7/27	8/12	8/21
Prior to boiling												
13.23	14.33	12.24	13.97	11.95	11.99	10.83	10.0	10.69	12.0	12.0	12.35	13.3
After boiling												
8.53	8.6	8.67	9.82	8.3	7.36	5.42	6.26	8.05	7.3	6.7	6.0	6.

The data on the study of the concentration of the exuded sap during the vegetation period prior to and after boiling show graphically that the errors on diagnosis of the exuded sap without boiling are inevitable. The sap concentration from June 4 to Aug. 21 without boiling did not decrease below 10%, although there were two irrigations and several light rains during the period.

The difference between the concentration of cell sap prior to boiling and after boiling for tomatoes during the vegetative period was in the range from 0.92% to 6.4%. This difference for potatoes was found to be in the range from 0.7% to 4.35%. We must note that Garin [5], while not describing the reason for this effect, showed in his work the difference between the concentration of sap exuded from fresh leaves and from leaves that had been killed by heating by submerging a hermetically sealed test tube with the leaf inside in boiling water for five minutes. The decrease in the concentration was observed to be in the range from 1.2% to 3.4%.

It is especially complex to use Lobov's method on tomatoes. The point is that the effect of summer wilting is sharply expressed in the south. One of the early signs of wilting is the increase in the concentration of water-soluble proteins in the tomato leaves. Therefore, the errors connected with the movement of proteins in the sap will be still larger when wilting begins.

The inapplicability of Lobov's method because of the indicated deficiencies brought us to the development of a method of diagnosing irrigation based on the concentration of the exuded sap.

The Method of Diagnosing Irrigation Based on the Concentration of The Exuded Sap

The water-soluble proteins are a source of error in M. F. Lobov's method. Since these proteins coagulate when heated, we carried out the careful boiling of the sap in small, sealed test tubes. Heating in closed test tubes was necessary in order that the steam from the water did not escape from the test tubes. The sap turned light and became completely clear when boiled. This made it possible to measure exactly the concentration with the aid of any refractometer. The collection of samples for analysis was made at the time recommended by Lobov, from 10 to 11 in the morning. Samples were taken from 15 tomato plants and from 9 to 12 potato plants, cutting off the lobes of the leaf. The samples from the tomatoes were from the leaf opposite the first flower cluster, and from the potatoes, from leaves of the middle stage. The severed lobes of the leaf were placed in illuminated glasses with covers and the glasses were then placed in a cardboard box. The severed specimens were transferred to the laboratory, where the analysis of the cell sap was carried out.

Having established the reason and source of the errors in Lobov's method, it was necessary to check the concentration of the sap after boiling to indicate the requirements of the plants for water.

In 1955, significant material was obtained on the concentration of sap prior to and after boiling as a result of carrying out experiments in containers. Knowing the soil moisture in the containers and the concentration of the exuded sap prior to and after boiling, we could approximately determine the preirrigation sap concentration for which the productivity of plants is highest. According to Lobov's recommendation, the irrigation of tomatoes and potatoes should begin with a sap concentration of 10%. It was found that the preirrigation concentration of boiled sap for tomatoes and potatoes is 7.5%. However it was necessary to check and verify these approximate data under field conditions. Field experiments were carried out with crops of potato and tomato in 1956 and 1957 with this as a goal. Irrigations were carried out in 1956 with the concentration of the cell sap 7.5 to 8%. This variant agreed with Smilyanets' [6] recommendation for potato when compared with irrigation based on soil moisture for tomatoes, and also agreed with the recommendation of Panenko [7]. The concentration (or more precisely the coefficient of refraction) of the sell sap was measured in all variants throughout the vegetation period.

The study of the dynamics of the change in the sap concentration (or, more precisely, the coefficient of refraction) after irrigation showed that at first, after irrigation, in the first several days the concentration of sap falls, then sharply increases for two or three days, and then falls for the second time, and after this drop the concentration again begins to increase. For example, after the irrigation of potatoes on June 7, a drop in the concentration took place for two days, then the concentration increased for two days, then fell for a period of four days, and after this began to rise steadily. The same dynamics for the change in the coefficient of refraction of the sap was also observed after a rain. For example, after a rain on June 8, the concentration of the cell sap on the plots of the dry control for potato and tomato also fell at first, then increased, and after this, fell again. Rain on June 21-23 resulted,at first,in a fall in the concentration on all plots; however, after June 25 the rise had already begun, and after June 27 there was again a slight decrease in the concentration. Such an irregular path of sap concentration interferes to a certain degree with diagnosis because one can easily get into difficulty if this feature of the dynamics is not considered. This is partly an inadequate method. However,

this irregularity of the path of the sap concentration cannot be an impediment for the use of the method on fixing irrigations. Recently Petinov and Lebedev [8], in studying the coefficient of refraction of the sap of tea leaves, found that it does not always react to an increase in soil moisture and for this reason they found it impossible to use the refractometer for fixing irrigations. Tea plants, of course, cannot be equated with vegetable plants.

Results of Field Experiments with Potato and Tomato

The experiments were made with variety Kur'er. The seeds were from the spring planting of 1955. Vernalization was done from March to April 5. Plantings were 70 by 35 cm on spaded ground. 200 g of an organic-mineral mixture was placed in each hole (30 g of granulated superphosphate and 25 g $(NH_4)_2SO_4$ with 1000 g of humus). The experiments had two repetitions. The size of the plot was 98 square meters. In the 1957 experiments the size of the plot was 115 square meters. The agricultural techniques were the same as in 1956.

The experimental scheme: I) irrigation with a soil moisture of 20-21% up to the time of tuber formation and 18-19% during the period of tuber formation; II) irrigation with a sap concentration of 7.5%; IIA) irrigation with a sap concentration of 8.5%; III) control (without irrigation).

The results of the experiment are given in Table 1.

The data for 1956 are more favorable for irrigation according to physiological indicators. The data for 1957, on the other hand, are somewhat favorable for the use of irrigation based on soil moisture. The conclusion can be made from the experiment that the concentration of the cell sap of 8.5% is high for potato. The optimal concentration for potato is 7.5%.

TABLE 1

Average Data Based on the Yield of Potato

Experimental variant	Total yield		No. of irrigation	Consumption of water, m^3/ha	Increased yield, centn. per 100 m^3 water	Experimental variant	Total yield		No. of irrigation	Consumption of water, m^3/ha	Increased yield, centn. per 100 m^3 water
	μ/ha	%					μ/ha	%			
	1956 experiment						1957 experiment				
I	268	167	5	3320	3.25	I	189	209	6	2400	4,10
II	281	176	5	2924	4.11	II	181	200	5	2375	3,85
III	160	100	—	—	—	IIA	120	134	2	987	3,60
						III	90	100	—	—	—

The experiments with tomatoes in 1956 were carried out with variety Mayak. The size of the plot was 105 square meters. There were two replicates. The seedlings were set in the ground on May 5. The scheme of the planting was a strip 100 x 30 x 30 cm. Prior to planting, there was a broadcast application of fertilizer of 10 centners/hectare of superphosphate and 8 centners per hectare of ammonium sulfate. The data of the yield are given in Table 2.

The experiments with tomatoes in 1957 were made using varieties Mayak and Stalingradets. The agricultural techniques were the same as in 1956. The data of the yield are given in Table 3.

The experimental variants with tomato: I) irrigated with a soil moisture of 19% prior to fruiting and 21-22% during the period of fruiting; II) irrigated with a sap concentration of 7.5-8%; IIA) irrigated with a sap concentration of 8.5-9%; III) control (without irrigation).

The data of the experiments for two years with tomato suggest the use of irrigation based on the concentration of cell sap. The productivity of the use of irrigation water is higher with irrigation based on physiological indicators.

TABLE 2

Average Data on the Yield of Tomatoes, Variety Mayak, 1955

Experimental variant	Total yield		Dry substance, %	Yield of dry substances, μ/ha	Number of irrigations	Consumption of irrigation water, m³/ha	Increase in yield per 100 m³ of water		
	μ/ha	%					Tomatoes μ	Dry substances	
								Kg	%
I	581.2	177	5.58	32.45	5	2992	8.8	49	100
II	655.3	205	5.4	35.4	5	2530	13.2	73.15	150
III	320.9	100	7.28	23.25	—	—	—	—	—

TABLE 3

Average Data on the Yield of Tomatoes, Variety Stalingradets, 1957

Experimental variant	Total yield on July 11		Number of irrigations	Consumption of irrigation water in m³ per ha	Increase in yield per 100 m³ of water	
	μ/ha	%			Tomatoes, μ	%
I	474.9	154	8	2410	6.8	100
II	470.2	152	8	2650	6.05	89
II A	455.1	147	4	1675	8.75	128
III	309.0	100	—	—	—	—

The data obtained from the field experiment show that one can manage irrigation according to the concentration of sap exuded from the leaves of potato and tomato plants. The irrigation water is used more productively with this type of management. Tomato is especially responsive. Technically, the measurements of the sap concentration are simpler than the determination of soil moisture. At the same time, irrigation according to physiological indicators gives better results so that attention should be given to this method of controlling irrigations. The physiological method allows for a more efficient use of irrigation water. It is more flexible because the growth conditions change in various years and "to ask" the plant when to irrigate it would be more exact than irrigation only on the basis of soil moisture. The inaccuracy of directing irrigation according to the soil moisture arises because we do not always know where and at what depth the active part of the root system is located. The average soil moisture in a large layer does not always indicate the demands of plants for irrigation.

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DECREASING PREHARVEST DROPPING OF APPLES AND PEARS IN THE CONDITIONS OF THE CRIMEA

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The results of investigations to test the effectiveness of chemical preparations as a means of combating preharvest dropping of apples and pears are described in this paper. The investigations were made in the period from 1952 to 1956, inclusively, on commercial varieties of fruit trees on the Stalin collective farm in the Bakhchisaraisk region (Vilino village), in the Crimea region. Three preparations were used in the experiments: α-naphthyacetic acid (ANU), the potassium salt of α-naphthyacetic acid (KANU) and 2, 4, 5-trichlorophenoxy-α-propionic acid (2, 4, 5-TP). The preparations were synthesized in our laboratory: ANU and KANU were prepared by Yu. A. Baskakov and the 2, 3, 5-TP by K. S. Bokarev. Trees of the following varieties were treated: apples— autumn varieties Napoleon, Pepin London, and Golden parmen, and winter variety Sary-Sinap; pears— autumn variety Bere-Bosk and winter variety Williams.

TABLE 1

The Effectiveness of the Action of Preparation of KANU and 2, 4, 5-TP on the Dropping of Apples, Variety Napoleon

Experimental variant	No. of dropped fruits for the period Sept. 1 to Sept. 11, 1956	
	Average per tree	As % of control
KANU (10 mg/1)	411	69.4
2,4,5-TP (20 mg/1)	386	65.2
Control	592	100.0

The preparations were applied in the form of water solutions. In all cases a starting solution was prepared first, and then a solution ready for use (working solution) was obtained after diluting the starting preparation up to the needed volume with water. The preparations for the initial solutions were in the following quantities: ANU 1 g per liter of water, KANU 5 g per liter of water, and 2, 4, 5-TP 1 g per 150 ml of ethyl alcohol. The initial solutions of ANU and KANU were prepared by heating water to the boiling point, stirring the water. Each of the preparations was tested using several concentrations: 5, 10, 20, and 40 mg per liter of water. The crowns of the trees were treated using a "Pioneer" horse-drawn sprayer. The spraying of the trees was done in the morning and evening hours (when there was no wind) 10 to 16 days prior to harvesting. The treatment was carried out during the period when individually healthy fruits began to fall. The crowns were sprayed both on the outside and on the inside, in an attempt to get a good wetting of the fruits and fruit stems. On the average, 40 liters were applied on the trees of variety Napoleon, which are quite large and 15 to 25 liters on the trees of the remaining varieties, which are smaller. We conducted our beginning experiments with the rules given in a number of our publications [1-4]. The experiments carried out during the indicated years showed that the treatment of trees with solutions of ANU, KANU, and 2, 4, 5-TP preparations significantly decreases the preharvest dropping of fruits. The preparations appeared to be most effective in the following concentrations: ANU and KANU 10 mg per liter of water (0.001% solution); 2, 4, 5-TP 20 mg per liter of water (0.002% solution). The ANU and KANU preparations appeared to be practically equal in the degree to which they affected the decrease of dropping of the fruits, but the 2, 4, 5-TP preparation somewhat surpassed the ANU and

KANU. We will give the data obtained in the experiment in 1956 with variety Napoleon (Table 1) to illustrate the effectiveness of the action of KANU and 2, 4, 5-TP.

A special experiment was established, the results of which are given in Table 2, in order to explain the effect of preharvest spraying of trees on the dropping of fruits injured by the apple worm and healthy fruits. It follows from this table that the diseased fruits fall in a significantly larger number than healthy fruits, and that treatment significantly decreases the falling both of healthy and of diseased fruits. We can also see from Table 2 that the effect of treatment on the falling of diseased and healthy fruits appears to be different for the different varieties. For the Napoleon variety, treatment decreased the dropping of healthy fruits to a greater extent than diseased fruits. For the Golden parmen variety, the treatment appeared to have practically the same effectiveness for fruits of both groups.

The results of the tests (1952-1956) showed that preharvest spraying of apple and pear trees with solutions of ANU, KANU, and 2, 4, 5-TP preparations is an effective technical agriculture method. We will present the results of the 1952 experiments (Table 3) to illustrate the effectiveness of this method.

The completed investigations make it possible to recommend the studied method for broad practical use. Its use in the conditions of the Crimea, which is one of the main regions for fruit production, makes it possible to decrease effectively the loss of commerical production of apple and pear plantings.

TABLE 2

The Effect of the KANU Preparation on the Preharvest Falling of Diseased and Healthy Apples

Variety and age of trees	Experimental variant	Number of fallen apples for four trees			
		Diseased		Healthy	
		No.	% of control	No.	% of control
Napoleon, 40 years	Control	5183	100	161	100
	KANU (10 mg/1)	931	18,5	8	4,9
Golden parmen, 17 years	Control	1767	100	225	100
	KANU (10 mg/1)	1181	66,8	145	64,4

The introduction of the described method is expedient for bringing about the use of the KANU preparation, which, according to our understanding, is already available for sale. This preparation is sufficiently effective as a means for decreasing the preharvest dropping of fruits. Moreover, it is easily soluble in water and this makes it very favorable for practical use. The 2, 4, 5-TP preparation is somewhat more effective than the ANU and KANU preparations, which are practically of equal value in their action, but it still remains to decide the question of the most favorable forms of its application and then to adjust its production.

In conclusion, we consider it our pleasant duty to convey our deep thanks to the director of the Section of Gardening and Viticulture of the Zemel' section of the Crimea region, P. F. Tsarev, the inspector of this section, S. M. Bokal, director of the Stalin collective farm of the Bakhchisaraisk region of the Crimea, G. A. Sarnets, the agronomist-horticulturist of this same collective farm, A. M. Belitchenko, and workers N. I. Oporovsk and A. S. Ovsynkov for their great help in the organization and completion of the work described in this article.

TABLE 3

The Effect of the KANU Preparation on the Preharvest Dropping of Fruits

Variety and age of trees	Experimental variant	No. of trees	Date of treatment	Date of harvest	No. of dropped fruits per hectare (100 trees) m	Harvest of fruit (excluding those dropped) per hectare (100 trees) m
Pepin London (autum variety), 47 years	KANU	31	Aug. 28	Sept. 18	1.7	16.3
	Control	26	Aug. 28	Sept. 18	3.0	15.0
Napoleon (autum variety), 40 years	KANU	30	Aug. 29	Sept. 16	2.6	40.1
	Control	24	Aug. 29	Sept. 16	7.7	35.0
Cyry-Sinap (winter variety), 20 years	KANU	204	Sept. 9	Sept. 29	2.0	22.8
	Control	124	Sept. 9	Sept. 29	4.8	20.0
Golden parmen (autumn variety), 17 years	KANU	41	Aug. 28	Sept. 10	1.0	17.3
	Control	46	Aug. 28	Sept. 10	2.3	16.0
Bere-Bosk (autumn variety), 23 years	KANU	12	Aug. 28	Sept. 16	1.2	16.1
	Control	12	Aug. 28	Sept. 16	2.3	15.0
Williams (winter variety), 23 years	KANU	26	Sept. 4	Sept. 30	3.4	34.1
	Control	24	Sept. 4	Sept. 30	7.5	30.1

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THE ROLE OF THE ZINC ELECTRODE IN THE TREATMENT OF SOILS WITH ELECTRIC CURRENT

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Investigations on growing plants on soil through which an electric current is passing indicate the possiblity of using this method for increasing the yield of agricultural crops [1-5]. However, there are also investigations in which this influence on the growth and development of plants is denied [6], or which suggest that this leads to the suppression of the plants. [7].

One of the reasons for the contradictions in the data in the literature is probably that the authors used different galvanic elements in their experiments, for example: copper-zinc [8], zinc-iron [9], iron-carbon [10], copper-copper [11], and zinc-carbon sinters [12]. The authors in all of these works did not think that the material of the plates played an important role in passing a current through the soil because the ions moving from the plates into the soil are in most cases microelements.

It follows from our investigations, where zinc and carbon plants served as the source of the galvanic current, that it is important to consider the composition of the plates when electrifying the soil. It was established that zinc plates decreased significantly in weight during the course of the experiment and that the loss in weight is in direct relationship to the strength of the current and duration of the experiment. The zinc plates decreased 140-150 g over six months in variants in which the strength of the current was 40 ma, but only 40-50 g when the strength of the current was 6 ma.

Considering the fact that zinc moves into the soil with the use of a zinc-carbon galvanic pair, we established experiments with zinc and without it. In the latter case, the effect only of the galvanic current showed on the plants. The work was done in 1957-58. Cotton and tomato were taken as subjects. The cotton was grown in a water culture on a Knop solution. Tomatoes were grown on a soil culture. There were 3 to 5 repetitions of the experiments.

In the experiments with the water culture of cotton, zinc and carbon plates were inserted in jars with the nutrient solution. The zinc plate was 270 mm long, 4 mm wide, and 0.8 mm thick; the carbon plate was 270 mm, 6mm and 6mm, respectively. The plates were connected by a lead; the strength of the current in the circuit was 1.5 μa. The control jars had no current. A month after the beginning of the experiment all plants in the jars in which there was a currant died. We think that the death of the plants was caused not by the immediate effect of the current, but by the high concentration of zinc ions in the water solution. The following experiment was established to support this proposition.

Similarly developing shoots of cotton at an age of six days were grown in jars on a Knop solution, First variant; two plates were placed in the solution and connected with a lead. The current was supplied from type 54-ASMTsG-5-P batteries. The strength of the current in the circuit was 1.5 μa. Second variant; the same with carbon plates, but the strength of the current in the circuit was 1.5 ma. Third variant; zinc and carbon plates were placed in the solution and the current was 1.5 μa. Fourth variant; strength of the current was 1.5 ma and the plates were zinc and carbon. Fifth variant; zinc and carbon plates were disconnected and there was no current. Sixth variant; control without plates.

Differences in the development of plants in the different variants were not noticed during the first six days. On the seventh day, the root system and cotyledons for plants of the second and fourth variants began to die. On the tenth day the beginning of the development of the accessory root hairs for plants of the control was noticed. At this time there was a sharply noted difference in the development of the root system for plants of the first and third variants. While the plants in the first variant varied little from the control, those in the third variant had weakly developed accessory roots, the fiber of the roots was absent, and only root hairs covered the main root. After two days the difference was still more noticeable in the fifth variant where there was no current, but dissolving of the zinc plates took place and the development of the plants was clearly poorer than in the control.

The determination of the pH of the Knop solution showed that the reaction was more basic in the third, fourth and fifth variants. Thus, while the pH in control solution at the end of the experiment was 5.08, it was 5.85 in the third and fourth variants. The toxic action of the zinc ions going into the solution from the zinc plates was explained as a result of this experiment. In those cases where the zinc plates were excluded and the current passed through the nutrient medium from batteries, the plants with a current of 1.5 ma were suppressed, but they differed little from the control with a current of 1.5 μa. We can assume that the decrease in the strength of the current can secure a positive, stimulating effect of the current on plants.

In view of the fact that the zinc ions in the water solution sometimes affect the root system when treatment takes place in the soil, we established experiments with tomatoes on a soil culture. There were three variants in the experiments. In the first variant, two carbon plates were put in the containers; in the second variant, zinc and carbon were put in the containers, and the third variant was the control without current; the plates were connected with leads. The current was produced by 54-ASMTsG-5-P type batteries. The current with a strength of 10 ma was turned on on March 21; 48 tomato seeds were planted in each container.

The plants of the first variant were more developed and their leaves appeared earlier than plants of the other variants.

In the variant with the zinc electrode, the plants grew poorly, and dwarf, underdeveloped plants were commonly found. The difference between the variants was maintained also for the establishment of buds. As in the experiments with the water culture of cotton, the plants in the zinc-carbon variant in the soil culture were suppressed in comparison to the control. A stimulation in the growth and development of plants was noticed in the carbon-carbon variant with the external source of current, in comparison to the control. Thus, it is necessary to use carbon plates with a current supplied to them from batteries when explaining the effect of electrifying the soil on the growth and development of plants.

When zinc electrodes are used, the metal ions pass into the soil in quantities toxic to plants.

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THE EFFECT OF FACTORS OF THE EXTERNAL ENVIRONMENT ON THE MANIFESTATION OF SEX CHARACTER IN THE CASTOR-OIL PLANT

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The problem of the sex of plants is brought to the attention of researchers more and more frequently. This is explained primarily by the fact that there are a large number of monoecious and dioecious plants among crop plants for which it is possible to increase the yield in proportion to the deviation of the sex ratio in the female direction.

The instability of sex of plants has been noted repeatedly in the literature [1-4]. Thus, Minina's work [4] showed that the water regime, the oxidizing-reduction processes in the cell, respiration and other physiological processes are changed under the effect of factors of the external environment such as temperature, soil moisture, atmospheric moisture, mineral fertilizers and the influence of gases. This change shows a great effect on the formation of sex characters in plants.

Investigators obtained the most tangible results with the reaction on plants in the early phases of growth [5]. However, concrete indications of the connection of the influencing factor with some period of development of the crop being examined were not obtained in most cases. Besides this, the formation of the generative organs undoubtedly depends on the stage of development of the plants in which the influence of one or another factor of the environment is taking place.

We influenced the basic factors of the environment of the castor-oil plant: the duration of the light period, the soil moisture and the nitrogen nutrition. The periods of influence were separated by the calculation of the duration of the light stage [6].

METHOD

The castor-oil plant was subjected to influence in the periods: 1) from the beginning of sprouting up to the beginning of differentiation of the point of growth into flower nodes, and 2) from the beginning of differentiation of point of growth up to the beginning of flowering. At the same time, there was influence from the beginning of sprouting continuously up to flowering. The duration of the light periods was 9, 14, 5, and 22 hours. The length of the day was regulated by rolling the trucks with the containers into a dark room and by supplementary lighting with electric lights. The water regime of the plants was changed by the creation of moisture conditions in the soil of 40, 60, and 80% of field capacity. Nitrogen fertilizer was applied in calculated doses as ammonium nitrate both prior to planting and also at the beginning of differentiation of the point of growth into flower nodes. 17 g of NH_4NO_3 per container was applied. During the vegetation period, fertilizers were applied in the irrigation water.

The experimental plants in our investigations were the single-flowered variety of the caster-oil plant, Kruglik 5, without lateral branches. The planting was done in vegetation containers holding 14.5 kg of soil. The fertilizer was applied at the beginning, using the following active ingredients per 1 kg of soil: 0.2 g N, 0.1 g P_2O_5, and 0.1 g K_2O. Irrigation was done daily, and it was based on weight. There were six repetitions of the experiment. Phenological observations of the experimental plants were carried out, calculating the male

and female flowers per raceme by the Podgurskaya method [7], and calculating the yield of the castor-oil plant.

The observations of plants in short-and long-day conditions showed that the long-day conditions of light favorable for passing through the light stage also favored the development of better productivity for the castor-oil plant. Thus, the long-day conditions are favorable for the formation of a large number of female flowers, with which the maximum production of seeds for these plants is also connected. The short day retards the passing through the light stage, but the number of female flowers does not change as a result of this. Otherwise, they have male flowers. When passage through the light stage is delayed on the short day, we noted a significant formation of flowers that increased their relationship toward the male side (Table 1).

The greatest effect that the duration of light has is in the period of passage through the light stage. We can see from Table 1 that further use of additional light or the short day does not cause any effective changes in the relationship of flowers. The influence of the photoperiods only during the first 10-12 days (light stage) gives the same results as keeping the plants in the indicated conditions for a long period (from the beginning of sprouting up to flowering).

As the data of our experiments show, the long day is the best condition for the formation of female flowers on castor-oil plants. Consequently, directing the sexual processes to the femal side is observed when conditions aid in the passage of the light stage. If the passage of the light stage is delayed, as on the short day, because of the unfavorable duration of light, then a significant number of male flowers is formed.

TABLE 1

The Effect of the Duration of Light on the Formation of the Generative Organs for Castor-Oil Plants (1953 experiment)

Experimental variant	No. of days prior to flowering	Number of flowers				Harvest of seeds per raceme, g
		Normal	♂	♀	Their relation	
Natural day	43	208	186	82	2.3:1	35.0
Short day	48	310	235	75	3.1:1	26.4
Long day	39	260	160	100	1.6:1	39.1
Short plus natural day	52	391	308	83	3.7:1	28.8
Natural plus short day	46	304	223	81	2.7:1	35.3
Long plus natural day	39	289	192	97	2.0:1	31.4
Natural plus long day	42	267	178	89	2.0:1	34.9

The experiments of a number of authors [5, 8] showed that a shift in sex to the female side was observed in conditions of a shortened day for short-day crops. The data of our investigations with long-day crops and the data of other authors with short-day crops make possible the conclusion that a duration of the day that would correspond to the demands of the growing organism in the period of passage through the light stage is necessary for processes connected with the formation of flowers.

Observations on the formation of male and femal flowers of castor-oil plants established the fact that inadequate moisture leads to the formation of fewer flowers, and an overabundant water supply results in a significant suppression of their numbers (Table 2).

The changes in the number of flowers on the central raceme of the castor-oil plant with various moisture conditions proceeds in a similar manner for both female and male flowers. In connection with this, their relationship hardly changes. As we know, investigators working with experiments carried out with representatives of a family of gourds arrived at another conclusion [4].

TABLE 2

The Effect of the Water Regime of the Soil in the Shift in Sex for Castor-Oil Plants

Soil moisture, %	No. of days prior to flowering	No. of flowers per raceme				Absolute weight of seeds	Yield of seeds per raceme, g
		Normal	♂	♀	Their relation		
40	45	225	156	69	2.2:1	260	69.2
60	39	280	196	84	2.3:1	233	100.0
80	41	296	202	94	2.1:1	233	96.4
40 + 80	45	349	252	97	2.7:1	222	91.2
80 + 40	39	283	196	87	2.4:1	264	98.7

The influence of changes in soil moisture by periods (the two last variants in Table 2) showed that a larger number of flowers is formed with an adequate supply of soil moisture in the period after the beginning of the differentiation of the point of growth into flower nodes, that is, after passing through the light stage. Although the passage of the light stage is significantly slowed (six days) with the influence of insufficient soil moisture, the formation of flowers in these conditions is reduced. The most decisive period in this connection is the second, after passage through the light stage.

However, the characteristic of the yield of the castor-oil plant showed that the decrease in the supply of soil moisture even in narrow ranges after the beginning of flowering (switch of all experimental containers to 60% moisture) can lead to a decreased collection of seeds.

In experiments with nitrogen fertilizers (Table 3), two dates for its application to the soil were used: prior to planting and in the period of differentiation of the point of growth into flower nodes. The application of fertilizer on the second date was accomplished with the irrigation water in two doses. The influence of a triple dose of nitrogen (0.6 g of active ingredient per 1 kg of soil) was tested.

The preplanting application of nitrogen retarded the passage of the light stage. However, this effect was not reflected on the formation of flowers. The influence of the nitrogen begins to appear after the light stage is passed, for which the reaction of the female flowers is insignificant; a more intensive formation of male flowers proceeds in these conditions. The relationship of male and female flowers increases sharply. Consequently, nitrogenous fertilizers aid in better formation of male flowers.

TABLE 3

The Effect of Excess Doses of Nitrogen on the Shift in Sex for Castor-Oil Plants

Experimental variant	No. of days prior to flowering	Number of flowers per raceme				Yield of seeds per raceme, g
		Normal	Male	Female	Their proportions	
Without fertilizers	36	204	125	79	1.5:1	30.3
N_3 prior to planting	39	351	266	85	3.1:1	46.0
N_3 at the beginning of differentiation of the point of growth	36	310	201	83	2.4:1	40.4

However, as the yield data show, the effectiveness of nitrogen fertilizers is so high that the collection of seeds increases 30 to 50%. When nitrogen is applied both prior to planting and in the vegetative period, a redistribution of male flowers on the raceme is observed. Instead of their normal low distribution, the flowers are distributed over the entire raceme and even have an accumulation on the upper part. Thus, the effect of nitrogen appears in the shift in sex for plants to the male side while the number of female flowers hardly changes.

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THE INTERRELATIONSHIP BETWEEN LEGUMINOUS AND GRASSY PLANTS IN MIXED PLANTINGS OF CORN AND SOYBEAN

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At the present time much importance is attached to the production of fodder, in particular protein fodder, in connection with the important tasks of the development of animal husbandry. The demand for protein is still increasing significantly so that now the basic fodder base in most regions of the country is corn. The cultivation of corn with leguminous crops is resorted to in many cases with the goal of increasing the nutrition of corn, based on the concentration of protein. The most suitable component in the conditions of the south is soy. However, mixed plantings of corn do not always give a higher yield of green mass and dry substance than corn in pure plantings, although the quality of the fodder is increased. This is explained by the fact that the competitive relations between the corn and the soy have a place in mixed plantings. The character of these relationships is accumulated in relation to the climatic conditions, soil fertility, and agricultural techniques.

TABLE

Yields of Green Mass and Green Ears of Corn in Mixture and Pure Plantings by the Square-depression Means, 70 × 70 cm

No. of plants in the sq.		Corn VIR-42 with Kuban soy			Corn VIR-42 with Illini soy		
Corn	Soy	Yield of green mass with ears	Which included: ears of corn	Which included: green mass of soy	Yield of green mass with ears	Which included: ears of corn	Which included: green mass of soy
2	—	279.2	103.4	—	279.2	103.4	—
2	1	267.2	93.0	10.8	254.3	88.2	17.3
2	2	257.7	92.5	13.8	253.3	87.2	19.2

During the 1954-1957 period, we studied mixed plantings of corn and soy. It was established that the negative effect of the interspecies competition can be significantly lowered by creating more favorable conditions of water supply and nutrition for plants. The means of planting the mixture, the thickness of the plants, and the relation between the components of the mixture by number have great significance. In the experiments in the northern Caucasus section of the Institute of Fooders, 86.6 centners of green mass per hectare were obtained in the dry year of 1954 with solid planting of corn in the pure form, but when corn was planted with soy, 79.4 centners were obtained. In the same conditions with planting of corn with soy in square depressions, 100.4 centners of green mass, calculated on a per hectare basis, were obtained.

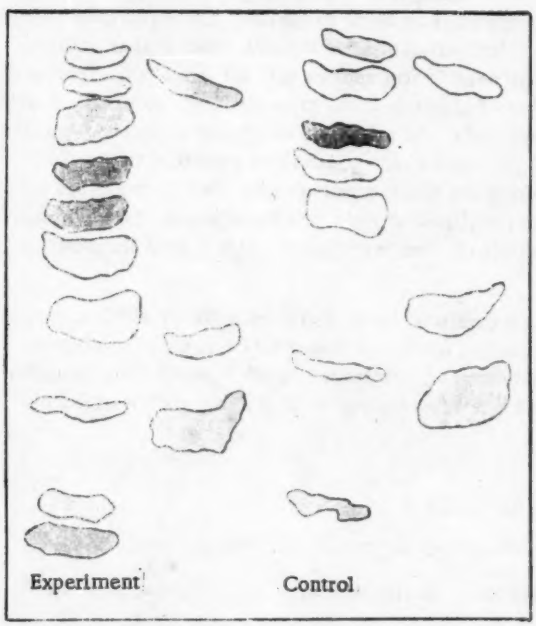
Thus, the plants suppress one another less with a square depression arrangement, with which the number of plants both of corn and of soy per unit area was significantly less than in solid plantings.

In 1955, these experiments were repeated. In contrast to 1954, there was a lot of rainfall in 1955 which favored the growth and development of the plants. In these condtions the gross collection of green mass of corn and soy in the mixed planting in many cases appeared to be higher than in the pure planting of corn. Thus, 254.4 centners of green mass per hectare were obtained with planting of corn only. When grown with two corn plants and one soy plant per depression, 276.0 centners of green mass were obtained. The collection of green mass reached 298.0 centners per hectare (that is, 44 centners more than in the pure planting) when two corn plants were grown with two soy plants in each depression. Accordingly, the collection of green cobs was 86 centners per hectare in the control, 91 centners per hectare in the mixed planting with one soy plant per depression, and 95 centners per hectare with two soy plants.

In 1957 we established a new experiment (Rostov Government Variety Station) in which two different varieties of soy were tested (see table).

The data given in the table show that the varieties which were used in the mixed planting also have a certain importance.

We must note that in 1957 there was no rainfall during a long period of time. Therefore, corn in the mixed planting experienced insufficient moisture to a greater degree than in pure planting. Thus the moisture of the leaves of corn in the pure planting during the day hours was already 71.4% by July 11, 70.2% in the mixed planting with Illini soy, and 69.8% with Kuban soy. There was also somewhat of a decrease in the mo sture of the leaves for soy variety Illini in mixed planting (69.5% against 70.7% in the pure planting).



Chromatograms of amino acids from the grain of corn. Left (experiment), amino acids from the grain of corn grown together with soy; right) in pure form (control); side by side) spots of "indicators": upper—lysine, middle—tyrosine, lower—tryptophane.

The supply of nitrogen and phosphorus to the plants was determined by the field method according to Magnits. These determinations, made several times in the morning hours, showed that a noticeable difference was not observed in the concentration of nitrates in the sap exuded from corn from the pure and mixed plantings. The concentration of phosphates in the sap of corn from the mixed planting was noticeably lower than in the sap from corn in the pure planting. It follows from this that corn and soy in the mixed planting apparently exhibit a deficiency in available phosphate, in addition to a water deficiency.

Thus, the data given here show that with favorable conditions of water supply and mineral nutrition in the mixed plantings of corn and soy, yields of green mass and ears can be obtained that are not lower than for the cultivation of corn in a pure form. With insufficient moisture and nutrient elements, the competition between the species increases and that leads to a decrease in the yield. It is not surprising, therefore, that many indications of an opposite nature can be found in the literature, [1, 10].

A large role in the interspecies relations is played by the different secretions of the plants which have a suppressing action on other species [2, 10]. According to this, the mutual suppression and weakening of the two different species grown together is not excluded even with an inadequate supply of moisture and nutrient substances for the plants. Therefore, it is far from an accident that pure plantings predominate in field culture. At the same time, in certain cases, the mixed crops were already an old tradition (vetchoat

mixtures, perennial grass mixtures). We consider the fact that mixed plantings normally consist of mixtures of legume plants with grasses is not a chance phenomenon, having in mind the possibility of the use by the nonlegume plants of nitrogen fixed by the tubercular bacteria.

Several authors [4, 8, 9] on the basis of data which they obtained deny the possibility of the use of the nitrogen of the tubercular bacteria by nonlegume plants prior to the death of the tubercules.

In order to check the position, we determined in 1957 the concentration of crude protein (as % of the absolute dry weight) in corn, variety VIR-42, which was planted with soy, variety Illini. The result of the determination was as follows: the leaves of corn from the pure planting had 8.5% crude protein, but from the mixed planting, 9.4%; the stems of corn had 2.5% and 3.6%, respectively, and the grain 12.4% and 12.9%.

In addition, a chromatographic analysis of the spread of amino acids from the grain and leaves of the corn was carried out. The batch of seeds and leaves taken for all variants was similar and the drops placed on the paper were measured with a micropipette. The amino acids were developed with ninhydrin. The spots of amino acids obtained on the chromatograms both from the leaves and from the grain of corn grown with soy appeared to be clearer according to the color and the number of the spots themselves greater than on the chromatograms of corn from the pure planting (see the scheme of the chromatogram of amino acids from the lysate of the grain). Obviously, under the effect of growing corn with soy, the concentration of proteins is not only increased, but changes in the qualitative character also take place.

The increase in the concentration of protein substances in grassy plants on their cultivation with leguminous crops was noted in a number of other works. For this, a decrease in the concentration of protein substances in the legume component of the mixture was observed. E. Russell [7] also noted that in the company of the legume with the nonlegume as a rule, the concentration of nitrogen for the nonlegume is higher and for the legume is lower, than on cultivating them in pure cultures. According to his idea, the leguminous plants having nitrogen fixed by the tubercular bacteria demand little nitrogen from the soil which makes possible the greater use of soil nitrogen by the nonlegume component. It also appears that the nonlegume component in the mixed planting ordinarily is half as high by number of plants as in the pure planting. However, in our experiment, the number of plants of corn both in the pure and in the mixed plantings was completely similar. Therefore, a similar amount of soil nitrogen both in the pure and mixed plantings is available in the given case for each plant of corn on the average. Not considering the given question completely decided, we are all the same, inclined to think that in many cases in the conditions of field culture, nitrogen fixed by tubercular bacteria can be used not only by legume crops, but also by the nonlegume crops if they are grown together.

The increase of the concentration of nitrogen in the corn when it is cultivated with soy also has practical significance. The green mass of soy in the mixed planting often constitutes only 5 to 6% of the normal mass. It is very essential if in the corn itself the concentration of proteins is 1 to 2% higher. Therefore, the collection of proteins from a hectare in the mixed planting is as a rule higher than in the pure planting of grass crops.

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THE INTRODUCTION OF COMPLETED WORKS INTO THE NATIONAL ECONOMY

THE USE OF GROWTH STIMULANTS IN THE PROPAGATION OF FRUIT-BERRY, FOREST, AND DECORATIVE PLANTS BY CUTTINGS

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The vegetative propagation of plants by means of cuttings has broad practical and theoretical significance. This means of propagation is widely used in horticulture and in selection. The essence of the cutting method is the fact that any part of the plant that is separated from the mother plant can develop in certain conditions into a separated organism. This characteristic was noted by man long ago and used by him in the propagation of plants by cuttings.

In our country the broad scope of the method of vegetative propagation of plants by stem cuttings was adopted during the years of the Soviet regime. Green plantings are widely used over the entire country in the cities, towns and villages; on state and collective farms, gardens are planted, large plantings along canals are established, and special plantations and nurseries are set up for the maintenance of forest protective strips. However, not all plants possess the same ability for root formation from cuttings. Plants to be propagated from cuttings can be divided conditionally into three groups, according to their ability to be propagated in this manner: easy, moderate, and hard-to-root. The most widespread means of vegetative propagation is that using green cuttings. Only easy-to-root plants are propagated by woody cuttings. The method of plant propagation by cuttings became still more widespread after the development of growth stimulants.

It has been shown through work done in the Soviet Union and in other countries that a whole series of physiologically active chemical compounds could be used as stimulants for rooting. Those most actively influencing the process of root formation appeared to be β-indolacetic acid (heteroauxin), β-indobutyric acid (IMK) and α-naphthyacetic acid (NUK) and their corresponding salts, which are called growth stimulants [1].

These substances aid in the rooting of cuttings of many hard-to-root plants and accelerate root formation for easy-to-root crops. They increase both the percent of rooting and the number of roots per cutting. The rooted, treated cuttings often outstrip the controls in the first period of their growth. However, the effectiveness of the action of these substances depends on the age condition of the mother plant and the cutting itself, and on the conditions for rooting.

Most plants are able to form roots at a young age and they lose this ability with age. The relationship of the process of regeneration to the age of the mother plant and the intensity of the growth processes also in connection with the effectiveness of the action of growth stimulants was established for many shrub and tree species [1-8].

Work on the study of physiology of the action of growth stimulants on the process of root formation for cuttings of different plants has been carried out since 1937 at the Institute of Plant Physiology of the USSR

Academy of Sciences. Broad investigation in this direction was also carried out at the Leningrad Forestry Academy [9], at the Tbilisi Agricultural Institute [10], at the Sukhumi Selection Station [11] and at the K.A. Timiryazev Agricultural Academy (TSKhA) [12].

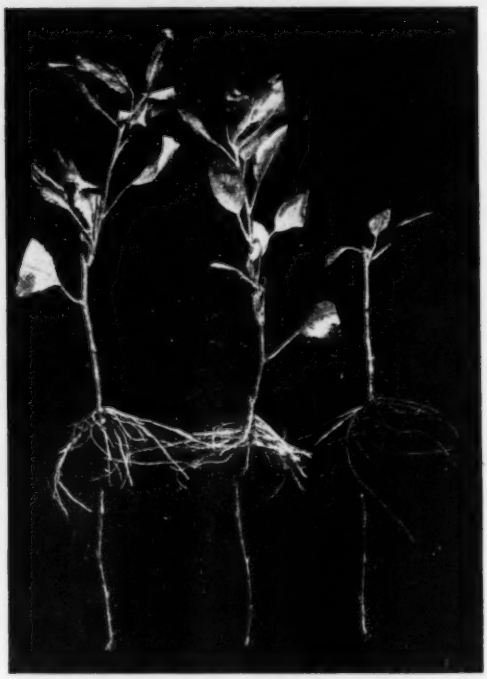

Fig. 1. Green cutting of apple, variety Raik. Above - treated with indolacetic acid in a concentration of 30 mg/1 for a period of 16 hours; below - controls.

The war held up this work for several years. However, after the war, the scale of the work on the use of stimulants for cuttings was greatly expanded. Further investigation showed that the stimulants were effective in increasing root formation for cuttings of different groups of plants, such as the fruit-berry, forest, decorative, and flowering plants. We carried out work with forest trees (oak, ash, bass-wood, maples — sharp-leaved, field, and tartar — hazelnut, honeysuckle, oleaster, buckthorn) on the Kameni Steppe (Voronezh region). Most of the cuttings for these groups of plants were green cuttings.

Green cuttings represent separate cut parts of green shoots of the growth of the current year with one and two internodes. In contrast to the woody cuttings, green cuttings are poor in nutrient substances and therefore those with few leaves, which exhaust the nutrient substances necessary for the formation of roots, are always picked. The successful rooting of green cuttings to a large extent depends on the date of cutting. The clipping of the cuttings cannot be coordinated with the calendar dates because the plants grow and develop in relation to metereorological conditions which are not the same in different years. It is necessary to obtain the green cuttings in relation to the growth conditions of the shoots. The cuttings of some plants (for example, apple, cherry, plum, gooseberry, elm, bass-wood, hazelnut and others) root best of all when they are taken from the growing shoots. Cuttings of other plants (lemon, oak, various maples, rose, Thuja, yew) form roots best of all when they are taken from shoots that are competing or have just completed their growth.

The investigations and data of other authors makes it possible to draw the following conclusions on the propagation of moderate and hard-to-root plant with green cuttings: 1) the best rooting and further intensive growth are obtained for shoots taken from green, but mature, shoots; 2) the signs of ripeness of the shoots are expressed in the following: when the apex of the green shoot is still herbaceous but the remaining part of the shoot begins to turn woody, it loses it brittleness and becomes elastic. The herbaceous and woody shoots are usually brittle. The green cutting ready for root formation reacts very actively to the treatment with a growth stimulant as a result of which the process of root formation is strengthened.

The use of growth stimulants in the propagation of fruit-berry plants has especially broad significance. We carried out the grafting of cherry, gooseberry, and currant on the Moscow Selection Station of the Institute of the Canning Industry and similar studies were made by V. I. Egorova in the Lenin pomological nursery, and also Tarasenko [12] and Polekarpov [13] in TSKhA and on the "Pamyat' Il'icha" and "Zavety Il'icha" collective farms below Moscow, Bromley in the Ivanteesk nursery (Pushkin region), and Shaitanov [14] at the Omsk Agricultural Institute. All of our experimental work showed that the preliminary treatment with heteroauxin, IMK, and NUK strongly accellerates and increases the emergence of planted cuttings. For example, when treated with a growth stimulant, the hard-to-root cherry, variety Lyubsk, rooted from 15 to 60%, moderate-rooting

Vladimir from 35 to 60%, and the relatively easy-rooting varieties Shubinka and Polevka up to 25-30%. Besides this, the process of root formation for the control cuttings proceeds with a lower intensity. After cherry, it is very important to have a crop of plum on the natural roots from seeds, from which the cuttings are also very responsive to treatment with growth stimulants [14, 15].

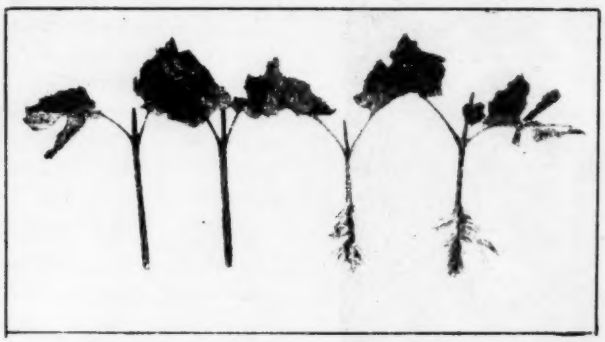

Fig. 2. Green cuttings of Tartar maple. Left - controls; right - treated with indolacetic acid in the concentration 50 mg/ l for a period of twelve hours.

Fig. 3. Green cuttings of rose. Left - controls; right - treated with heteroauxin, 150 mg/ l for a period of fourteen hours.

Many comparatively easy-to-root crops react very strongly to the use of growth stimulants. On the state farm "Yuzhnye Kultury", where up to 15 to 20 thousand cuttings of lemon are set out each year, we managed (1950-51) to obtain rooting of up to 80 to 90% by treatment of the semiwoody cuttings with a growth stimulant. The process of rooting was drawn out for the control cuttings and in the final calculation, the cuttings rooted up to 35 to 50% of the normal number. The same thing can be noted for grape, which suckers relatively easily; however, 100% rooting was never obtained. Heteroauxin or other growth stimulants helped in the 100% rooting of woody cuttings of grape and caused an abundant formation of roots on cuttings with growth stimulants; the necessity for the laborious process of heeling-in dropped because the growth stimulant affecting root formation at the same time retards the opening of the leaves.

Undoubtedly it is desirable to use these substances also with the grafting of easy-to-root, but practically important crops. For example, geranium is quite easily and rapidly propagated with cuttings, but the use of these substances is very desirable with most propagation of this commerical crop. Thanks to the acceleration of rooting, the cuttings begin growth earlier and the plants obtained from them are more vigorous and yield a greater above-ground mass; thus, the production of geranium oil is increased [20, 21].

The concentrations and times of treatment depend on the species of the experimental plant and the degree of lignification of the cuttings. The approximate concentrations for semilignified cuttings is as follows: heteroauxin, 100 to 200 mg/l; IMK and NUK, 20-50 mg/l; time of treatment from eight to sixteen hours.

The K. A. Timiryazev Institute of Plant Physiology, Academy of Sciences of the USSR, long ago carried out work on the introduction of these substances into the practice of horticulture and, starting in 1941, published methodological directions and instructions [22-26]. These substances are now in practical use in the propagation of plants by cuttings. The wide distribution of growth stimulants in the various economies of our country shows the usefulness of their action.

Such hard-to-root and practically important plants as apple and pear are special cases. Apple and pear have special notes in the literature [27, 28, 29] on the rooting of cuttings with the help of growth stimulants. There are some varieties of apple that form roots relatively easily. The forest apple, Kitaika, Paradizka, variety Taezhnaya and several others belong in this group. However the cuttings of these varieties of apple are not always able to regenerate roots even with the use of growth stimulants. In the first place, this process depends on the physiological condition of the tissues of the cuttings. We managed to root cuttings of apple variety Raik taken in a weakly lignified condition up to 40% and the hard-to-root variety Autonovka up to 25% by treating them with IMK. However, the mass propagation of apple and pear by cuttings, even with the use of growth stimulants, has not at the present time been set.

The method of preliminary treatment of the shoots on the mother plant (girdling, etiolation) has possibilities for strengthening root formation, particularly for hard- to-root plants, but it is expedient to use a mixture of two stimulants (double treatment) in several cases. It further follows to apply and introduce widely growth stimulants in a mixture with ascorbic acid into the practice of grafting: this mixture appeared to be more active in strengthening root formation than one growth stimulant [29].

In conclusion, it is necessary to note that the growth stimulant shows an effective action on root formation in that case where the age and physiological condition of the cutting, temperature, light, moisture, subtrate, and several other factors of the external environment are considered.

The successful use of growth stimulants in tree and shrub planting [30-33] and the planting of vegetable sprouts [34, 35] must be mentioned. Such plants as cabbage, tobacco and several others react especially actively to the use of growth stimulants. Soaking the roots of cabbage sprouts for a period of four hours in a solution of the potassium salt of heteroauxin (20 mg/l strongly accelerates growth and increases its yield. The use of such work is being carried out according to our instructions by gardeners and laymen. The treatment of the root system of planted seedlings with a solution of the potassium salt of heteroauxin in a concentration of 30 mg/l for a period of 16 to 20 hours aids in more rapid rooting. We might add in this connection that this preparation can be sprinkled on the soil around plants that have been set out in spring up to the time of the opening of the leaves

Growth stimulants can show even more effective action on the formation and growth of roots of transplanted crops when their use is combined with the optimum conditions of nutrition and temperature.

Along with the practical use of growth stimulants, there is much work being conducted on the study of the physiology of the action of these substances. The accumulated practical material makes it possible to propose that the nature of the action of growth stimulants is apparently included in the fact that they strengthen metabolism, aid the flow of nutrient and other substances to the place of root formation and create conditions for the use of the latter in the process of formation and growth.

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DELAY OF THE SPROUTING OF THE TUBERS OF DIFFERENT VARIETIES OF POTATO UNDER LONG STORAGE

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It is very undesirable to have potato tubers sprout when they are in storage for a long time. In forming shoots, the tubers sharply reduce the reserve nutrient substances, need much moisture, wither, and become shriveled. Because of this, the commerical, nutritive, and technological qualities of the tubers decrease.

It has been established that the methyl ester of α-naphthyacetic acid is effective in delaying the sprouting of potato tubers [1, 2]. This substance in the form of a 3.5% dust in powdered clay was recommended for delaying the sprouting of the tubers of food potatoes [3-6]. This dust, called preparation M-1, has already been applied in the USSR for a number of years in commercial quantities and has a broad practical use [3].

In this article we will present the results of an experiment on the delaying of sprouting of the tubers of 189 different varieties of potato with the help of preparation M-1. Tubers harvested in 1952 were taken for the experiment. A large part of the variety material was obtained in the fall of 1952 from: A) Scientific-Research Institute of potato culture (Korenevo Station, Moscow-Ryazansk Railroad); B) All-Union Plant Culture Institute (Leningrad, 44 Gertsena ulitsa); C) Polar section of the All-union Plant Culture Institute (Khibin, Murmansk Region). The remaining material (D), obtained in the spring of 1952 from different places (VSKhV, Scientific-Research Institute of potato culture, TSKhA Vegetable Station), was planted in the fields of the K. A. Timiryazev Institute of Plant Physiology, USSR Academy of Sciences (Moscow, Lenin Mountains) and the resulting harvest was used for the experiment.

The experiment was established in December of 1952 in the special potato storage, Combine No.3, Fruit-Vegetable Ministry of Trade, RSFSR.

The treatment of potato tubers was done with a 3.5% dust preparation M-1. The tubers were treated using 3 g of dust per 1 kg of potatoes. Clay jars containing about 2.5 kg of tubers were used for storage of the treated and control (not treated with the dust) potatoes. The tubers stored in the jars were treated in layers, with the layers one tuber thick. Dusting the potatoes was done with the help of a silk screen with a mesh of 0.25 × 0.25 mm. All jars were closed on top with wrapping paper and tied with twine. The results of the experiment were determined in the second ten days of June, 1953. The weight of the treated shoots and the decrease in the weight of the tubers were calculated for the period of storage (the so-called physiological loss, the sum of the consumption of substances in the process of respiration and the loss of water as a result of transpiration).

The investigations that were carried out showed that the tubers of different varieties of potato form shoots to the extent of 1% to 20% of the original weight of the tubers when stored for a long time. Thus, under the influence of the M-1 preparation, the Avrora variety formed 0.1% sprouts, and the Epron variety, 8%. Considering the intensity of the sprouting of the untreated tubers (control) at the end of the storage time, we combined all varieties of potato into seven groups. Thus, for example, the varieties having from 1% up to 2.5% sprouts were combined into group I; the varieties forming 2.5% to 4% in group II, etc.

TABLE

The Effect of Preparation M-1 on the Sprouting of Tubers of Different Varieties (data given at % of the original weight of the tubers)

Groups of varieties based on the intensity of sprouting of treated tubers		Control		Preparation M-1	
Group	Varieties	Sprouts	Physiological loss	Sprouts	Physiological loss
I	Avrora (B)	1.6	6.0	0.1	3.8
	Clar Innes (C)	2.4	5.9	1.1	1.6
II	Krest'yanka Redinga (C)	2.9	2.9	0.2	2.1
	Foran (B)	3.3	4.6	1.5	3.9
	Local late (Drogobych region) (B)	3.8	5.7	2.3	6.4
III	Vekaragis (A)	4.7	3.7	0.8	0.8
	Bul'ba (A)	5.6	4.8	1.1	2.5
	Kalev (D)	5.6	4.0	2.5	3.5
	Vol'tman (A)	5.4	6.1	3.9	4.2
IV	Appatit (C)	6.9	5.2	0.7	3.7
	Rannyaya Roza (C)	6.7	4.9	1.2	2.1
	Korenevskii (D)	7.6	5.5	2.5	4.0
	Severyanin (C)	7.9	6.1	3.7	2.9
V	Flemingshtarke (C)	8.8	5.0	0.36	2.8
	Lorkh (D)	8.4	5.1	1.4	2.8
	Varba (D)	8.8	4.9	2.4	3.4
	Epikur (C)	9.1	3.6	3.0	2.2
	Dun Erli (B)	8.5	3.4	4.3	2.3
	Phytofluorine-resistant: hybrid No. 42 (B)	10.0	5.8	8.0	4.2
VI	Kardinal (B)	10.7	5.2	0.8	2.1
	Severnaya Roza (D)	10.7	3.9	1.2	1.9
	Oktyabrenok (D)	12.2	4.6	2.6	2.2
	Peredovik (D)	11.2	8.2	3.5	3.6
	Erren Benner (A)	11.0	7.1	4.9	4.6
	Sovetskii (D)	11.8	6.9	5.4	5.2
VII	No. 2009	14.7	4.4	0.4	4.2
	Berlikhingen (B)	14.8	5.4	1.5	2.5
	Khibin frost-resistant (C)	13.4	4.1	2.3	1.7
	Laima (B)	15.7	6.7	3.3	2.6
	Voronezhskii (D)	15.3	6.8	4.4	3.5
	Epron (D)	14.5	10.1	8.0	5.2

All groups and some examples characterizing them are given in the table. In addition, a list of all varieties according to the established groups is given in the article. The characteristic of each group is given in parentheses: the title letter denotes the place of cultivation; the first number is the physiological loss of the potato tubers in percent; the second number is the weight of the shoots for the treated tubers in percent; the their number is the physiological loss for treated tubers in percent.

Group I: Avror (B; 6.0; 0.1; 3.8); Clar Innes (C; 5.9; 1.1; 1.6); Merkur (A; 7.3; 0.6; 3.8); Molinae – dikar' (B; 4.0; 0.5; 5.0); Sabina (B; 4.9; 0.5; 3.2).

Group II: Akkerzegen (A; 5.2; 0.0; 3.5); Blokhinger (A; 3.4; 0.6; 2.0); Botitselli (A; 5.9; 0.8; 3.0); Byrypaevskii (A; 6.2; 0.1; 1.1); Immertrei (A; 3.4; 0.1; 1.7); Krest'yanka Redinga (C; 2.9; 0.1; 2.1); Dén (A; 3.6; 1.2; 2.4); Kapella (B; 4.3; 0.2; 3.1); Katadin (A; 3.2; 1.4; 2.2); Local late, Dorogobych region (B; 5.7; 2.3; 6.4); Maereker (A; 4.7; 0.0; 3.0); Olev (A; 4.7; 1.0; 3.0); Rote Meize (A; 5.4; 0.2; 3.5); S. Cathahitrum (B; 4.3; 1.7; 5.9); Seyanets Domina (A; 3.9; 0.4; 3.5); Foran (B; 2.1; 0.2; 2.0); Érgol'd (C; 3.9; 0.3; 2.1); Érlain No. 2 (A; 2.8; 0.6; 2.3); Po-888 (B; 5.6; 1.2; 1.8); P 8-658 (B; 3.0; 1.3; 1.9).

Group III: Arminius (A; 48; 0.0; 3.8); Beate Paul'sen (A; 3.8; 1.2; 2.7); Bona (B; 2.6; 0.1; 1.9); Bul'ba (A; 4.8; 1.1; 2.5); Vekoragis (A; 4.7; 0.8; 0.8); Bobbie Burns (A; 6.9; 1.5; 1.7); Vol'tman (A; 6.1; 3.9; 4.2); Volzhanin (D; 4.4; 25; 29); Gluckspiel' (A; 7.9; 0.5; 4.8); Dagmar (B; 52; 0.9; 2.9); Iycheva Varane (A; 5.3; 1.1; 2.9); Iycheva Kolane (B; 5.2; 0.5; 3.7); Kalev (D; 4.0; 2.5; 3.5); Kvitte (A; 7.2; 1.6; 3.6); Kazota (C; 3.0; 0.6; 1.7); Kalitinets (C; 2.7; 0.2; 1.0); Kameraz (A; 4.2; 0.6; 1.9); Kitting (B; 3.6; 0.8; 1.5); leptostigma (B; 6.8; 1.2; 5.2); Murmansk (D; 5.4; 1.2; 3.4); local, Dorogobych region (B; 10.3 2.4; 7.1); M. Intere (A; 4.8; 0.9; 2.7); Narodnyi (A; 3.5; 1.8; 3.5); N'yak (C; 2.2; 0.6; 1.5); Néks (A; 4.4; 0.6; 2.9); Oval'gel'be (A; 4.4; 2.2; 2.9); Rurae New Yorker (A; 4.8; 1.1; 2.7); Spartuoles (B; 5.0; 0.2; 2.8); Sestra Imandry (C; 3.0; 1.1; 2.0); Flemingskot (A; 7.4; 0.0; 3.5); Khibin double-yield (C; 4.6; 1.7; 3.9); Tsentifoliya (A; 2.5; 1.1; 1.2); Érntedank (A; 3.1; 1.5; 2.5); P 8-210 (B; 2.7; 1.2; 1.8); B 249 (B; 3.7; 1.2; 2.4); B 215 (B; 4.0; 1.4; 1.7); B 42 (B; 4.5; 1.8; 3.6); P 8-261 (B; 2.5; 1.0; 2.1); B 176 (B; 4.3; 0.9; 3.1); B 275 (B; 5.2; 2.4; 3.0).

Group IV: Appatit (C; 5.1; 0.7; 2.9); Aberdin Favorit (C; 4.2; 0.9; 1.8); Antje (A; 5.1; 2.0; 3.7); Vaises Resl' (A; 4.4; 1.0; 1.8); Vermont (C; 3.4; 0.8; 1.9); Gemma (A; 6.7; 1.7; 5.1); Gigant (A; 4.9; 1.3; 3.3); Dekbar Rover (A; 4.9; 2.0; 21); Elena (C; 3.7; 0.8; 1.8); Iycheva Valge (B; 6.2; 0.8; 4.4); Iycheva Tal'vik (B; 4.7; 0.1; 2.0); Inverness Favorit (A; 4.5; 2.5; 3.0); Komreid (A; 4.0; 2.1; 8.9); Konsuragis (A; 5.2; 2.0; 3.2); Kornea (A; 2.2; 2.2; 2.5); Korenevskii (D; 5.5; 2.5; 4.0); Kungla (D; 6.0; 2.1; 4.2); King George (D; 3.8; 1.4; 2.2); Lembitu (A; 5.8; 1.2; 2.8); Meve (A; 8.7; 0.9; 4.0); Magnum bonum (A; 4.4; 1.4; 2.5); Narymchanin (A; 5.2; 2.4; 3.1); Pavni (B; 3.1; 0.8; 1.6); Prozentragic (A; 6.5; 0.0; 2.8); Rannyaya Roza (C; 4.9; 1.2; 2.1); Sebago (B; 3.3; 0.6; 1.8); Sibberperle (A; 3.9; 0.7; 2.2); Severyanin (C; 6.1; 3.7; 2.9); Sidling (A; 5.7; 2.0; 2.3); Taborki (B; 5.0; 0.7; 3.8); Ural'skii (B; 4.8; 1.5; 41); Tseruliya (B; 5.3; 0.6; 2.2); Érfolg (A; 4.9; 1.2; 3.5); R 8-218 (F; 3.0; 2.3; 2.1).

Group V: Varba (D; 4.9; 2.4; 3.4); Gol'den Marvel (A; 5.1; 2.4; 2.5); Q de la Halle (A; 5.4; 2.3; 3.2); Hindenburg (A; 6.8; 3.9; 4.6); Dun Érli (B; 3.4; 4.3; 2.3); Zarnitsa (D; 6.9; 2.3; 3.6); Iycheva Kommunar (A; 5.2; 1.0; 3.9); Ioganna (A; 7.4; 4.0; 4.6); Kobbler (A; 4.6; 2.1; 2.2); Lorkh (D; 5.1; 1.4; 2.8); Linda (D; 6.3; 2.0; 4.3); Monopol' (A; 4.8; 1.3; 3.0); Moskovskii (A; 5.4; 1.8; 2.1); Mont blanc (A; 6.4; 1.2; 2.7); Mazhestik (B; 4.1; 2.1; 2.0); Macbeth's Castle (A; 4.0; 3.1; 3.4); Pilot (C; 4.6; 2.2; 2.9); Primunes (B; 6.2; 0.6; 3.1); Perl (A; 5.4; 1.9; 2.2); Sekvoya (A; 4.0; 0.4; 2.1); Snezhinka (C; 6.0; 1.0; 2.0); Smyslovskii (A; 4.6; 0.9; 2.1); Seyanets 97-29 (D; 6.1; 1.6; 3.2); Stepnyak (A; 6.7; 3.1; 3.4); Seyanets 27-95 (D; 3.7; 1.8; 4.6); Triumph (A; 7.2; 2.9; 3.6); Tulunskii (B; 2.8; 0.7; 1.5); Fanfare (A; 4.3; 0.6; 1.2); Flemingshterke (B; 5.0; 0.6; 2.8); Fitoftoroustoichivyi hybrid No.42 (B; 5.8; 8.0; 4.2); Khibin skorospelka (A; 5.2; 2.8; 3.0); Khibiny-3 (C; 4.1; 3.4; 3.3); Érlain (A; 5.4; 3.4; 3.7); Épikur (C; 3.6; 3.0; 2.2); P-8-227 (B; 4.1; 3.1; 2.5); P-9-833 (B; 3.5; 1.0; 1.16).

Group VI: Akvila (A; 6.7; 0.5; 2.2); Agronomicheski (B; 6.6; 1.9; 2.3); Boyar (A; 5.9; 2.3; 5.0); Bellidun (B; 3.8; 2.3; 2.1); Gretskott (C; 3.4; 3.7; 2.2); Grenimark (A; 6.1; 2.7; 0.7); Tesma (A; 6.3; 3.5; 3.1); Dun Perl (A; 6.4; 2.0; 2.5); Imandra (A; 5.8; 2.2; 2.0); Kleimoor (A; 8.8; 2.9; 5.0); Kardinal (B; 5.2; 0.8; 2.1); Kol'skii (C; 6.3; 0.6; 2.7); Oktyabrenok (D; 4.6; 2.6; 2.2); Paul Wagner (B; 5.5; 1.4; 2.3); Pontiac (B; 5.7; 2.3; 4.6); Peredovik (D; 8.2; 3.5; 3.6); Primula (B; 3.5; 3.2; 3.0); Priekul'skii rannii (A; 8.5; 5.1; 5.1); Sovetskii (D; 6.9; 5.4; 5.2); Seyanets Sibniskhoz (A; 8.5; 4.5; 5.3); Severnaya Roza (D; 3.9; 1.2; 1.9); Ul'yanovskii (D; 11.1; 2.8; 3.1); Toni (B; 5.0; 3.1; 2.9); Fryumelle (B; 5.1; 0.2; 7.1); Flava (B; 4.6; 1.1; 3.0); Fryubote (C; 3.8; 1.8; 2.1); Khibinka (A; 4.4; 2.5; 3.4); Khuma (A; 6.0; 2.9; 2.9); Élla (D; 5.3; 2.2; 2.0); Brren Keiren (A; 6.5; 3.1; 4.2); Érren-Bénner (A; 7.1; 4.9; 4.6); Érika (A; 6.6; 4.1; 4.0); Érren Skout (A; 4.7; 1.5; 3.7).

Group VII: Dr. Yu. Aamisepp (B; 4.9; 3.0; 2.8); Bogarnyi (A; 4.9; 2.0; 2.7); Berlikhingen (B; 5.4; 1.5; 2.5); Voronezhskii (D; 6.8; 4.4; 3.5); Virulake (B; 7.7; 1.5; 1.5); Gelbe Rose (B; 4.1; 1.1; 1.9); Zikingen (D; 5.7; 2.9; 2.9); Kotnov (B; 5.3; 6.1; 3.6); Krasnoufimskii (B; 5.1; 2.5; 2.4); Laima (B; 6.7; 3.3; 2.6); Moskvich (D; 6.6; 6.5; 3.5); Magdeburger Blaue (C; 4.8; 3.6; 4.5); Osthilfe (A; 8.7; 8.1; 6.0); Priekul'skii (B; 9.7; 8.5; 6.8); Potomac (A; 9.4; 0.4; 1.9); Sverdlovskii (D; 6.1; 4.8; 2.3); Khibin frost-resistant (C; 4.1; 2.3; 1.7); Érika (B; 5.3; 1.7; 2.5); Épron (D; 10.1; 8.1; 5.2); Yubel' (D; 6.5; 4.5; 2.8); P-859 (B; 6.3; 2.7; 3.1); A-26 (B; 5.0; 3.4; 2.9); No 2009 (B; 4.4; 0.4; 4.2); Y-8-233 (B; 3.9; 1.1; 2.6).

The data show that the M-1 preparation delays sprouting and, as a rule, decreases the physiological loss of tubers of all varieties of potato in storage. The degree of the effect of the M-1 preparation on the process of sprouting and on the physiological loss of tubers is related to some degree to the variety characteristics of the potato and this must be considered in the use of the indicated preparation under commercial conditions.

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METHODS

AN INSTRUMENT FOR THE DETERMINATION OF THE QUANTITY OF RADIATION (PHOTOINTEGRATOR)

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There is a need in a number of physiological experiments for the measurement of the quantity of radiation, that is, the energy hitting a given surface for a certain length of time. Similar data, for example, can be necessary in the investigation of the connnection of the growth of plants with the light regime under field conditions.

For similar measurements, a light measuring instrument could be connected; for example, a selenium cell connected to the type SG6 self-recorder could be used, but the high price and awkwardness of the latter make it unsuitable for the indicated task, in particular for work under field conditions.

A sufficiently simple and reliable working photointegrator, which gives good results for work under field conditions in the summer, is described below [1].

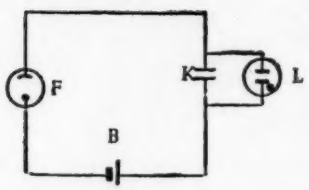

Fig. 1.

The principle of the working of the instrument is not new and is the basis for a whole series of similar instruments described in the literature [2-7]. However, it seems desirable to us to describe our instrument for the following reasons. In the first place, in spite of its simplicity, reliable results in field conditions can be attained only with the use of parts of a specific brand and with the observance of several general precautions in assembly. Secondly, the optical part and partially the electrical scheme of out instrument differ from those instruments described earlier. Finally, apparently, it is of interest to describe an instrument made entirely from domestic parts.

The principle of the working of the instrument is given in the following (Fig. 1).

The vacuum photoelectric cell, F, and the condenser, K, are connected in series with the battery, B. When the photoelectric cell is lighted, a certain current, i, flows out, charging the condenser. After a certain period of time, which depends on the intensity of the light, the voltage in the condenser reaches some quantity, V_0, for which the neon lamp, L, connected in parallel to the condenser, is lighted. At this point, the voltage in the condenser begins to fall rapidly in proportion to the discharge of the condenser through the neon light. This impulse of voltage can be calculated by the type SB-1M/100 electromechanical meter used in the assembly for measuring radioactivity. The charge of the condenser up to voltage V_0 is reached only after a certain charge Q_0 is accumulated on the face of the condenser (because $V = CQ$, where C is the capacity of the condenser). This charge depends on the production of the flow of $\underline{i}$ and its duration; $Q = i \cdot t$. Insofar as the flow of $\underline{i}$, in its turn, is proportional to the intensity of the light hitting the photocell, it is clear that the charge Q_0 and consequently the voltage for lighting the neon light will be reached only after the flow of a certain quantity of light on the photocell. Thus, every case of lighting the neon light indicates that a certain quantity of light has fallen

on the photocell and a normal number of impulses (shown by the mechanical meter) characterize the quantity of radiation (the dose).

It is necessary that the following basic conditions be met for success of the indicated scheme.

The charge of the condenser must be determined by the flow through the photocell as a result of its lighting. However, in order to meet the condition, it is necessary that:

1) the loss through the electrodes of the photocell is not substantial. The size of this flow depends on the clarity of the glass of the photocell and on the method of reinforcing the photocell. It is important, in particular, to protect the photocell from moisture;

2) the condenser must have a sufficiently high resistance to insulation; that is, the leakage through its facing must be held to a minimum because leakage of the condenser decreases the number of counted impulses. It is obvious that the condenser must also be protected against moisture;

3) the leakage by the external surface of the neon light must also be small because the neon light is connected in parallel to the condenser and, consequently, any leakage in the light is equivalent to leakage by the condenser. The leakage by the condenser will be less as the voltage in it is less and therefore it is desirable that the voltage for lighting the neon light be as low as possible. This condition is one of the basic conditions in the selection of a neon light.

A photograph of the entire instrument is shown in Fig. 2.

The instrument consists of an "optical gauge" and a housing with the mechanical meter and the source of power. The scheme of the "gauge" is shown in Fig. 3.

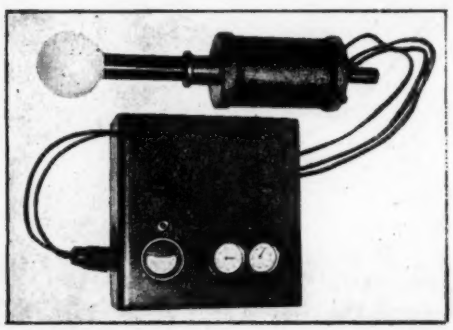

Fig. 2

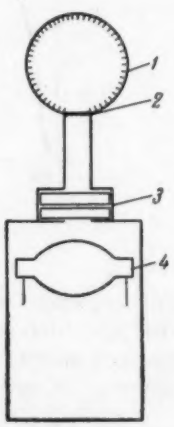

Fig. 3

The light hitting the frosted glass spere is dispersed proportionally inside of it and, partially proceeding through the frosted glass (2) by way of the tube and through the light filter (3), falls on the photocell (4), a TsV3 or TsV6. Using the sphere makes it possible to measure the spherical radiation. If it is desirable to measure the intensity of the light falling on a flat surface, it is sufficient to take the sphere and replace it with frosted glass, M. The light filter (3) consists of colored glass SZS-14, 6 mm thick, and colored glass ZLS-11, 3 mm thick. The spectrum curve of the sensitivity of the type TsV photocell in combination with the indicated light filters is shown in Fig. 4.* Thus, the instrument is equally sensitive to a significant degree to light in the range of 400-700 mμ; this is, it measures, in essence, the physiological radiation and, consequently, is a photoelectric phytoactinometer.

The condenser charged through the photocell and both neon lights is also located inside the gauge, in addition to the photocell. The gauge is hermetically sealed with the help of lead or paranite gaskets for protecting the working parts from moisture.

* The author extends his thanks to M. I. Épshtein for calculating this curve.

The gauge is connected by a flexible wire in the casing, in which the remaining electrical part of the instrument, the mechanical meter and the voltmeter for measuring the voltage of the battery, are set up.

The electrical scheme of the instrument used in our field experiments in the summer of 1957 is shown in Fig. 5.

The impulse of voltage flowing at the time of lighting the MN-7 neon light is carried through the condenser in 120 $\mu\mu$f to thelighted electrode of the neon cold thyratron MKhT-90. The latter is lighted and the condenser charged by the batteries in 1 μf is discharged through the thyratron and mechanical meter. Because there is always some positive voltage established with the help of the resistance of some 16 megohms on the lighted electrode and there exists a glow discharge, the sensitivity of the thyratron is sharply increased and that impulse which is received when the first neon light is lit is completely adequate for its wear and tear.

We noted above that the choice of a neon light in a circuit of photocell has a significant importance. The MN-7 light that we used has a sharp threshhold of lighting and a large difference between the potentials of lighting and extinguishing.

Because some current passes through the photocell even in the dark (dark current), the instrument can compute in the dark. However, if the leakage in the condenser and neon light is fairly high, so that they are not able to charge up to the necessary potential for lighting, then there will be no dark impulses. Moreover, low intensities of light in that case cannot cause the appearance of impulses and that is even more undesirable than the presence of a background. If there is a dark background, then it must calculated from the measured number of impulses. It is more difficult to make the correction in the second case when there is something of a minimum intensity, below which the instrument does not count.

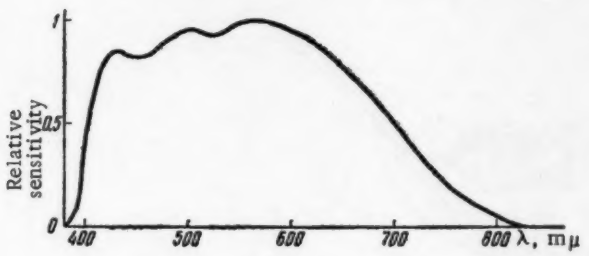

Fig. 4

The proportionality between the rate of calculation and the intensity of light was verified in the laboratory with the help of neutral light filters and appeared to be satisfactory. The maximum number of impulses in a minute which the instrument reliably registered was about 400. In the typical case, one division of the meter corresponded to 180,000 erg/ cm^2 or about 0,0043 cal/ cm^2.

The photointegrator described was used in field experiments carried out in the summer of 1957 in the Scientific-Research Institute of Potato Culture near Moscow [1].

There were three instruments in the work. They worked more than 60 days, during which the light day ranged from 12 to 16 hours per day, that is, about 1,000 hours. At this time the instrument gauged to background radiation counted more than 2.5 million impulses. The SB-1M meters for the impulses were calculated for 1 million impulses and during the summer they were replaced with mechanical meters.

The protection of the battery from the action of the sun's rays is of practical importance. The BAS-80 batteries used served without failure during the entire period of the field experiments and without a significant decrease in their voltage. We not that the demanded current was less than 4 milliamperes with a rate of calculation of 200 impulses per minute.

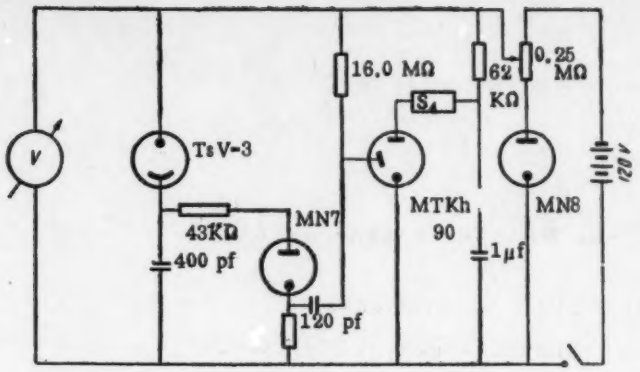

Fig. 5

In conclusion, the authors extend their thanks to Professor A. A. Nichiporovich, according to whose suggestion the original work was undertaken.

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AN INSTRUMENT FOR MEASURING LEAF AREAS

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It is usually necessary to determine the area of leaves taken from the plant, and occasionally of those directly on the plant, for many of the physiological investigations and work on the study of the dynamics of the growth and development of plants. The application of the weighing method (outlining the contours of the leaf on paper and then weighing the cut-out contour for this purpose) or the determination of the area with the help of a polar planimeter is inaccurate and generally very difficult.

A method for measuring the area of leaves with the help of the so-called photoelectric planimeter was developed by E. G. Petrov and N. I. Gavrilov in 1939. In 1954, a photoelectric planimeter (Fig 1) which differed basically from the model described by E. G. Petrov and N. I. Gavrilov in 1939, was developed at the optical-mechanical works of the K. A. Timiryazev Agricultural Academy. Systematic measurements of the leaf area of a number of vegetable plants (radish, lettuce, carrot, cabbage, potatoes, beet, tomato, onion, and others) were made in 1954-1957 with the help of this instrument. The construction and the technique of working with the photoelectric planimeter are described in this article, as well as the results of its use in a four-year experiment.

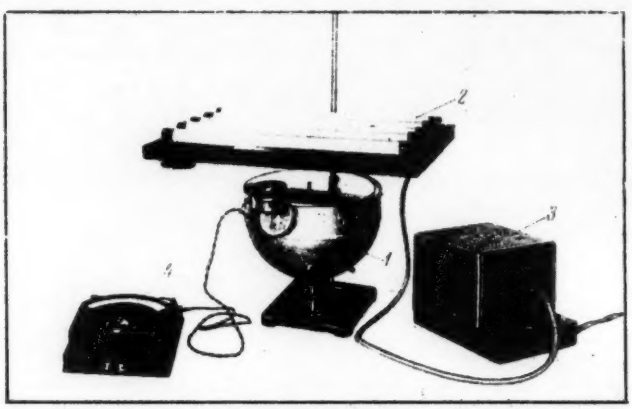

Fig. 1. Photoelectric planimeter for measuring leaf area. 1) Hemisphere with the photoelement; 2) rack with DC-15 lights; 3) reactor box; 4) galvanometer.

The photoelectric planimeter of the new form consists of the following parts: 1) the planimeter proper consisting of the hemisphere with a glass top, closed cover with the photoelement included in the housing and a regulating diaphragm with a small lever; 2) the light structure, consisting of a rack with the daylight lamps attached to it; 3) the reactor box with the choke to the daylight lamps; and 4) the galvanometer, connected to the photoelement with an electric cord.

TABLE 1

Measuring Leaf Area by Different Methods

Leaf No.	Photoelectric planimeter				Weight method					Planimeter					
	Reading on the galvanometer scale	Leaf area, cm^2	Deviation from the average, %		Wt. of 1 cm^2. of leaf	Wt. of the cut-out of the leaf contour	Leaf area in cm^2.	Deviation from the average, %		Outline of the leaf contour by hand			Leaf contour obtained by photographic method		
			Average	Max.				Average	Max.	Leaf area, cm^2.	Deviation from the average, %		Leaf area, cm^2.	Deviation from the average, %	
											Average	Max.		Average	Max.
1	51	196.6	0.00	+1.85	0.663	1417.9	213.7	+0.01	+1.18	211.6	−0.20	+3.58	219.7	+0.03	+1.67
2	45.4	176.0	−0.13	+3.41	0.649	1234.4	188.2	0.00	−4.09	193.8	+0.05	−1.13	186.9	−0.27	−2.39
3	21.3	82.9	0.00	+1.93	0.661	568.0	86.0	+0.05	−2.03	87.8	0.00	+1.75	85.5	−1.52	−2.98
4	37.9	145.9	+0.27	−1.44	0.658	1012.8	153.8	0.00	+1.82	156.2	0.00	+0.71	153.9	−0.80	−9.3
5	14.0	54.5	0.00	+0.15	0.700	411.2	58.5	+0.36	+3.59	56.4	0.00	−0.83	49.8	+3.77	+5.73
6	30.3	117.4	+0.03	−1.02	0.656	767.6	117.1	−0.01	−2.29	−117.6	0.00	+1.78	114.5	0.00	+3.16
7	24.9	97.2	0.00	−1.23	0.651	622.6	95.7	+0.22	+1.54	96.3	+0.17	+3.80	90.0	−0.11	−3.16
8	8.0	30.8	0.00	+0.52	0.622	202.5	32.5	+0.12	−4.31	30.6	+0.01	−2.58	29.1	+1.94	+7.40
Average	—	—	+0.02	+3.41	—	—	—	+0.09	−4.31	+ −	+0.00	+3.80	—	+0.42	+7.40

The operation of the instrument is based on the principle of work of the spherical photometer; that is, the changes in the size of the exposure of the internal surface of the hemisphere. The size of the exposure depends on the dimensions of the light flow falling on the upper glassed-in portion of the hemisphere and proceeding on to its inner surface. The light flow will be at a maximum when the glass surface of the hemisphere is clear. If a part of it is covered with a nontransparent, flat object, then the size of the light flow is decreased proportionally to the area of the object.

It is necessary, when measuring the area of leaves, to figure what the leaf blades have different gradations in their green color and that they partially let light pass through. Practically, the green leaf fully absorbs the blue region of the spectrum with a wave length if 450 mμ and less. Therefore, the measurements of leaf area with the help of a photoelectric planimeter must be carried out in the indicated region of the spectrum. For this, a blue filter is placed in front of the photoelement, absorbing all of the remaining portion of the spectrum with a wave length greater than 450 mμ. This leads to the fact that the green leaf located in the path of the light flow is comparable to a nontransparent object.

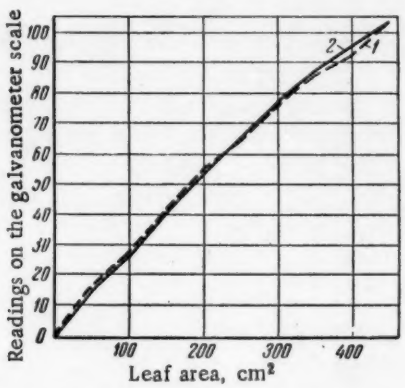

Fig. 2. Curves of measurements on standards of black paper (1), and from leaves (2).

The measurement of the area of leaves with the help of a photoelectric planimeter has great advantages in comparison to other methods, particularly in saving time. Thus, according to the data of E. G. Petrov and N. I. Gavrilov (1939), outlining the leaf contours with an ordinary planimeter took 10 hours and 41 minutes for the measurement of the sum of the area of leaves of 100 in², cutting out contours and the determination of the area by the weight method, 9 hours and 32 minutes, but measurement with a photoelectric planimeter, 1 hour and 27 minutes.

The comparative data of the measurements of the area of leaves by the different methods are given in Table 1. Each leaf was measured five times and then the deviations were calculated as a percent of the average leaf area, which is given in Table 1. We can see from the average and maximum deviations that the measurement of the leaf areas by the photoelectric planimeter does not yield in accuracy to the ordinary planimeter, but the weighing method appears to be less accurate.

It is shown above that the green leaf is comparable to a nontransparent object because of the blue light filter placed in front of the photoelement. This makes it possible to measure accurately the area of leaves of different thicknesses and various gradations of green color. Graphically, this is shown on the graph (Fig.2) where the two curves of the measurement of standards with areas from 50 up to 400 cm², prepared from black paper and of leaves are given. We can see from the graph that the curves practically coincide. A similar picture was obtained in another test experiment where squares similar in size taken from leaves of various thicknesses and color were measured on the photoelectric planimeter for cabbage, tomato, lettuce, radish and cucumber. The readings on the scale of the galvanometer for all squares that were obtained were practically similar. The matching results also appeared when measuring leaves that were fresh and those that had lain in the herbarium.

Thus, the photoelectric planimeter in measuring the area of leaves gives greater economy of time, guarantees high accuracy of measurements and it is possible to use it for a large number of the different plants. This is very important for such crops as carrots and other carrot-like plants, legumes and others for which the leaf blades are sharply divided, when the use of all other methods are excluded.

The photoelectric planimeter must be calibrated prior to being used. For this, the needle of the galvanometer, with the help of the diaphragm, is fixed on the end of the scale that corresponds to the maximum light in the interior of the hemisphere when its glass surface is clear and the cover is closed.

It is necessary to carry out a calibration of the instrument prior to measuring the area of the leaves. This includes the conversion of the figures based on the scale of the galvanometer into units of leaf area (cm^2). For this purpose, area standards are prepared from flat black paper in the form of circles or squares with areas from 5 up to 300 cm^2 with intervals every 5 to 10 cm^2. The described standards are placed in order on the glass portion of the hemisphere, the cover is closed, and the number of divisions on the galvanometer counted. It is necessary to check the accuracy of the setting of the needle of the galvanometer prior to each calculation (it must be on the extreme right division of the scale).

We carried out several thousand measurements of leaf areas of radish, lettuce, spinach, peas and beans in 1954-1956. For this, we somewhat altered the order of work with the photoelectric planimeter indicated above, in order to save time. The leaves destined for measurement were first placed between sheets of herbarium paper and put under a press for one day. After this, it was not necessary to close the cover because the leaves were well-smoothed, and this eliminated excess movements in working with the planimeter. Because of this, the time for measuring one leaf dropped to one-half minute. The calibration of the instrument in this case is also carried out without the cover.

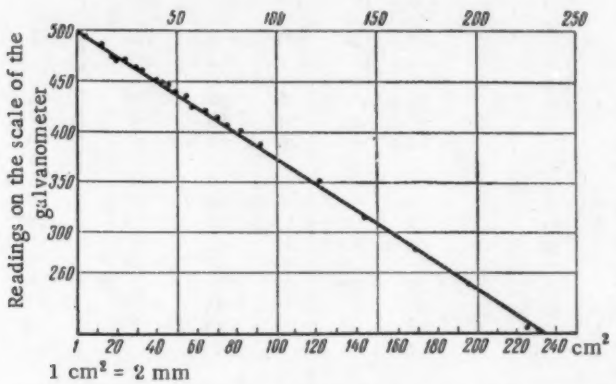

Fig. 3. Calibrated graph on the photoelectric planimeter.
(1) Readings on the scale of the galvanometer.

The readings obtained on the galvanometer and their corresponding leaf areas are used for constructing a calibrated graph. In order to obtain a continuous series of numbers for changing the readings of the galvanometer into leaf areas, intermediate points were taken and a working table was derived on the basis of the data obtained. Below we give the graph (Fig. 3) and Table 2, which we used in 1954-1957 in the measurement of areas of leaves of vegetable crops.

When measuring the standards of black paper, both in the form of circles and squares, we noted that the squares and circles give similar results on the galvanometer up to an area of approximately 200 cm^2. However, as soon as the corners of the square reach the part of the glass surface of the hemisphere that is within 2-2.5 cm from the edge, the results are altered. Further checking of this effect showed that the outer side of the glass surface in the area 2-2.5 cm from the border does not give accurate results in measuring the area of leaves (the so-called "edge effect"). Therefore, in future work, we placed a circle of black paper 2 cm wide on this border so that the measurements with leaves do not enter into the zone of inaccurate results. The calibration of the instrument was carried out with this closed circle.

We used different methods that facilitated and simplified the measurements in measuring the most variously formed leaves. Thus, the very heavy leaves of cabbage were first cut into pieces from a certain area from the middle of the leaf and the pieces were measured on the photoplanimeter. Very fine leaves were placed all together, lying flat side by side. Long petioles (for example, on bean leaves) were cut off and measured all together, lying side by side, etc. In all cases, none of the measured portions of the leaf were placed in the zone of the edge effect.

TABLE 2

Working Table for the Determination of Leaf Area (based on the calibrated graph for the photoelectric planimeter)

Galvanometer scale	0	1	2	3	4	5	6	7	8	9
200	235	234	233.5	232.5	232	231	230	229.5	228.5	228
210	227	226.5	225.5	225	224	223	222.5	221.5	221	220
220	219	218.5	217.5	217	216	215.5	214.4	213.5	213	212
230	212.5	210.5	210	209	208	207.5	206.5	205	205	204
240	203.5	203	202	201.5	200.5	200	199	198	197	196
250	195.5	195	194	193.5	192.5	192	191	190	189.5	188.5
260	188	187	186	185.5	184.5	184	183	182.5	181.5	181
270	180	179	178.5	178	177	176	175.5	174.5	174	173
280	172.5	171.5	171	170	169	168.5	167.5	167	166	165
290	164.5	163.5	163	162	161.5	160.5	160	159	158	157.5
300	156.5	156	155	154	153.5	152.5	152	151	150.5	149.5
310	148.5	148	147	146.5	145.5	145	144	143	142.5	141.5
320	141	140	139.5	138.5	138	137	136	135.5	135	134
330	133	132.5	131.5	130.5	130	129	128.5	127.5	127	126
340	125	124.5	124	123	122	121.5	120.5	120	119	118
350	117.5	116.5	116	115	114	113.5	112.5	112	111	110.5
360	109.5	109	108	107.5	106.5	105.5	105	104	103.5	102.5
370	102	101	100	99.5	98.5	98	97	96	95.5	95
380	94	93	92.5	91.5	91	90	89	88.5	87.5	87
390	86	85	84.5	83.5	83	82	81.5	80.5	80	79
400	78	77.5	76.5	76	75	74.5	73.5	72.5	72	71
410	70.5	69.5	69	68	67	66.5	65.5	65	64	63.5
420	62.5	61.5	61	60	59.5	58.5	58	57	56	55.5
430	54.5	54	53	52	51.5	50.5	50	49	48.5	47.5
440	47	46	45	44.5	43.5	43	42	41	40.5	39.5
450	39	38	37.5	36.5	36	35	34	33.5	32.5	32
460	31	30.5	29.5	29	28	27	26.5	26.5	25	24
470	23.5	22.5	21.5	21	20	19.5	18.5	18	17	16
480	15.5	14.5	14	13	12	11.5	10.5	10	9	8.5
490	7.5	7.0	6	5	4.5	3.5	3	2	1.5	0.5
500	0									

The use over a period of four years on the vegetable station of TSKhA of the photoelectric planimeter for measuring the area of leaves of the most varied forms of crops make it possible boldly to recommend its use by investigators who must have information on the leaf surface of the plant.

SUMMARY

A photoelectric planimeter for measurement of leaf areas is described which consists of a hemisphere with a glass top and a white inner surface. The illumination of the latter is measured with a photocell supplied with a blue light filter.

The illumination of the internal surface of the hemisphere is inversely proportional to the area of a surface located on the grass of the instrument.

The planimeter yields a high degree of accuracy, sharply (by 6 to 7 times) reduces the measurement time compared to that required by other methods and permits one to determine the area of leaves of complex profile (unbelliferous, leguminous and other plants). The instrument yields accurate results for plants of various thickness and various tinges of green.

Received March 13, 1958

ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN RUSSIAN BIO-SCIENCES LITERATURE

Abbreviation (Transliterated)	Significance
AMN SSSR	Academy of Medical Sciences, USSR
AN SSSR	Academy of Sciences, USSR
BIN	Biological Institute, Botanical Institute
FTI	Institute of Physiotherapy
GONTI	State United Sci-Tech Press
GOST	All Union State Standard
GRRRI	State Roentgenology, Radiology, and Cancer Institute
GTTI	State Technical and Theoretical Literature Press
GU	State University
I Kh N	Scientific Research Institute of Surgical Neuropathology
IL (IIL)	Foreign Literature Press
IONKh	Inst. Gen. and Inorganic Chemistry (N. S. Kurnakov)
IP	Soil Science Inst. (Acad. Sci. USSR)
ISN (Izd. Sov. Nauk)	Soviet Science Press
Izd.	Press
LEM	Laboratory for Experimental Morphogenesis
LENDVI	Leningrad Inst. of Dermatology and Venereology
LEO	Laboratory of Experimental Zoology
LIKhT	Leningrad Surgical Institute for Tuberculosis and Bone and Joint Diseases
LIPZ	Leningrad Inst. for Study of Occupational Diseases
LIPK	Leningrad Blood Transfusion Institute
Medgiz	State Medical Literature Press
MOPISh	Moscow Society of Apiculture and Sericulture
MVI	Moscow Veterinary Institute
MZdrav	Ministry of Health
MZI	Moscow Zootechnical Institute
LOKhO	Leningrad Society of Orthopedic Surgeons
NIIZ	Scientific Research Institute of Zoology
NINKhI	Scientific Research Institute of Neurosurgery
NIU	Scientific Institute for Fertilizers
NIUIF	Scientific Research Institute of Fertilizers and Insecticides
NIVI	Veterinary Scientific Research Institute
ONTI	United Sci. Tech. Press
OTI	Division of Technical Information
RBO	Russian Botanical Society
ROP	Russian Society of Pathologists
SANIIRI	Central Asia Scientific Research Institute of Irrigation
SANIISh	Central Asia Scientific Research Institute of Sericulture
TsNII	All-Union Central Scientific Research Institute
TsNTL	Central Scientific and Technical Laboratory
VASKhNIL	All-Union Academy of Agricultural Sciences
VIG	All-Union Institute of Helminthology
VIEM	All-Union Institute of Experimental Medicine
VIR	All-Union Institute of Plant Cultivation
VIUAA	All-Union Institute of Fertilizers, Soil Science, and Agricultural Engineering
VIZR	All-Union Institute of Medical and Pharmaceutical Herbs
VNIRO	All-Union Scientific Institute of Fishing and Oceanography
ZIN	Zoological Inst. (Acad. Sci. USSR)

Note: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us. - Publisher.

RUSSIAN JOURNALS FREQUENTLY CITED

[Biological Sciences]

Abbreviation*	Journal*	Translation
Agrobiol.	Agrobiologiya	Agrobiology
Akusherstvo i Ginekol.	Akusherstvo i Ginekologiya	Obstetrics and Gynecology
Antibiotiki	Antibiotiki	Antibiotics
Aptechnoe Delo	Aptechnoe Delo	Pharmaceutical Transactions
Arkh. Anat. Gistol. i Émbriol.	Arkhiv Anatomii Gistologii i Émbriologii	Archives of Antomy, Histology, and Embryology
Arkh. Biol. Nauk SSSR	Arkhiv Biologicheskikh Nauk SSSR	Archives of Biological Science USSR
Arkh. Patol.	Arkhiv Patologii	Archives of Pathology
Biofizika	Biofizika	Biophysics
Biokhimiya	Biokhimiya	Biochemistry
Biokhim. Plodov i Ovoshchei	Biokhimiya Plodov i Ovoshchei	Biochemistry of Fruits and Vegetables
Bot. Zhur.	Botanicheskii Zhurnal	Journal of Botany
Byull. Éksptl. Biol. i Med.	Byulleten Éksperimentalnoi Biologii i Meditsiny	Bulletin of Experimental Biology and Medicine
Byull. Moskov. Obshchestva Ispytatelei Prirody, Otdel Biol.	Byulleten Moskovskogo Obshchestva Ispytatelei Prirody, Otdel Biologicheskii	Bulletin of the Moscow Naturalists Society, Division of Biology
Doklady Akad. Nauk SSSR	Doklady Akademii Nauk SSSR	Proceedings of the Academy of Sciences USSR
Éksptl. Khirurg.	Éksperimentalnaya Khirurgiya	Experimental Surgery
Farmakol. i Toksikol.	Farmakologiya i Toksikologiya	Pharmacology and Toxicology
Farmatsiya	Farmatsiya	Pharmacy
Fiziol. Rastenii	Fiziologiya Rastenii	Plant Physiology
Fiziol. Zhur. SSSR	Fiziologicheskii Zhurnal SSSR im. I. M. Sechenova	I. M. Sechenov Physiology Journal USSR
Gigiena i Sanit.	Gigiena i Sanitariya	Hygiene and Sanitation
Izvest. Akad. Nauk SSSR, Ser. Biol.	Izvestiya Akademii Nauk SSSR, Seriya Biologicheskaya	Bulletin of the Academy of Sciences USSR, Biology Series
Izvest. Tikhookeanskogo N. I. Inst. Rybnogo Khoz. i Okeanog.	Investiya Tikhookeanskogo N. I. Instituta Rybnogo Khozyaistva i Okeanografii	Bulletin of the Pacific Ocean Scientific Institute of Fisheries and Oceanography
Khirurgiya	Khirurgiya	Surgery
Klin. Med.	Klinicheskaya Meditsina	Clinical Medicine
Lab. Delo	Laboratornoe Delo (po Voprosam Meditsiny)	Laboratory Work (on Medical Problems)
Med. Parazitol.	Meditsinskaya Parazitologiya i Parazitarnye Bolezni	Medical Parasitology and Parasitic Diseases
Med. Radiol.	Meditsinskaya Radiologiya	Medical Radiology
Med. Zhur. Ukrain.	Medichnii Zhurnal Ukrainskii	Ukrainian Medical Journal
Mikrobiologiya	Mikrobiologiya	Microbiology
Mikrobiol. Zhur.	Mikrobiologichnii Zhurnal	Microbiology Journal
Nevropatol., Psikhyat. i Psikhogig.	Nevropatologiya, Psikhyatriya i Psikhogigiena	Neuropathology, Psychiatry and Psychohygiene
Ortoped., Travmatol. i Protez.	Ortopediya, Travmatologiya i Protezirovanie	Orthopedics, Traumatology and Prosthetics
Parazitol. Sbornik	Parazitologicheskii Sbornik	Parasitology Collection
Pediatriya	Pediatriya	Pediatrics
Pochvovedenie	Pochvovedenie	Soil Science
Priroda	Priroda	Nature
Problemy Éndokrinol. i Gormonoterap.	Problemy Endokrinologii i Gormonoterapii	Problems of Endocrinology and Hormone Therapy
Problemy Gematol.	Problemy Gematologii i Perelivaniya Krovi	Problems of Hematology and Blood Transfusion
Problemy Tuberk.	Problemy Tuberkuleza	Problems of Tuberculosis
Sovet. Med.	Sovetskaya Meditsina	Soviet Medicine
Sovet. Vrachebny Zhur.	Sovetskii Vrachebnyi Zhurnal	Soviet Physicians Journal
Stomatologiya	Stomatologiya	Stomatology

*BRITISH-AMERICAN TRANSLITERATION SYSTEM.

(continued)

(continued)

Abbreviation	Journal	Translation
Terap. Arkh.	Terapevticheskii Arkhiv	Therapeutic Archives
Trudy Gelmint. Lab.	Trudy Gelmintologicheskoi Laboratoriya	Transactions of the Helminthology Laboratory
Trudy Inst. Genet.	Trudy Instituta Genetiki	Transactions of the Institute of Genetics
Trudy Inst. Gidrobiol.	Trudy Instituta Gidrobiologiya	Transactions of the Institute of Hydrobiology
Trudy Inst. Mikrobiol.	Trudy Instituta Mikrobiologiya	Transactions of the Institute of Microbiology
Trudy Inst. Okean.	Trudy Instituta Okeanologiya, Akademii Nauk SSSR	Transactions of the Institute of Oceanology, Academy of Sciences, USSR
Trudy Leningrad Obshchestva Estestvoisp.	Trudy Leningrad Obshchestva Estestvoispytatelei	Transactions of the Leningrad Society of Naturalists
Trudy Vsesoyuz. Gidrobiol. Obshchestva	Trudy Vsesoyuznogo Gidrobiologicheskogo Obshchestva	Transactions of the All-Union Hydrobiological Society
Trudy Vsesoyuz. Inst. Eksptl. Med.	Trudy Vsesoyuznogo Instituta Eksperimentalnoi Meditsiny	Transactions of the All-Union Institute of Experimental Medicine
Ukrain. Biokhim. Zhur.	Ukrainskii Biokhimichnii Zhurnal	Ukrainian Biochemical Journal
Urologiya	Urologiya	Urology
Uspekhi Biokhimiya	Uspekhi Biokhimiya	Progress in Biochemistry
Uspekhi Sovremennoi Biol.	Uspekhi Sovremennoi Biologiya	Progress in Contemporary Biology
Vestnik Akad. Med. Nauk SSSR	Vestnik Akademii Meditsinskikh Nauk SSSR	Bulletin of the Academy of Medical Science USSR
Vestnik Khirurg. im. Grekova	Vestnik Khirurgii imeni Grekova	Grekov Bulletin of Surgery
Vestnik Leningrad. Univ. Ser. Biol.	Vestnik Leningradskogo Universiteta, Seriya Biologii	Journal of the Leningrad Univ., Biology Series
Vestnik Moskov. Univ., Ser. Biol. i Pochvov.	Vestnik Moskovskogo Universitera, Seriya Biologii i Pochvovedeniya	Bulletin of the Moscow University, Biology and Soil Science Series
Vestnik Oftalmol.	Vestnik Oftalmologii	Bulletin of Ophthalmology
Vestnik Oto-rino-laringol.	Vestnik Oto-rino-laringologiya	Bulletin of Otorhinolaryngology
Vestnik Rentgenol. i Radiol.	Vestnik Rentgenologii i Radiologii	Bulletin of Roentgenology and Radiology
Vestnik Venerol. i Dermatol.	Vestnik Venerologii i Dermatologii	Bulletin of Venereology and Dermatology
Veterinariya	Veterinariya	Veterinary Science
Vinodelie i Vinogradarstvo	Vinodelie i Vinogradarstvo SSSR	Wine-Making and Viticulture
Voprosy Klin.	Voprosy Klinicheskie	Clinical Problems
Voprosy Med. Khim.	Voprosy Meditsinskoi Khimii	Problems of Medical Chemistry
Voprosy Med. Virusol.	Voprosy Meditsinskoi Virusologii	Problems of Medical Virology
Voprosy Neirokhirurg.	Voprosy Neirokhirugii	Problems of Neurosurgery
Voprosy Onkol.	Voprosy Onkologii	Problems of Oncology
Voprosy Pitaniya	Voprosy Pitaniya	Problems of Nutrition
Voprosy Psikhologii	Voprosy Psikhologii	Problems of Psychology
Voprosy Virusologii	Voprosy Virusologii	Problems of Virology
Vrachebnoe Delo	Vrachebnoe Delo	Medical Profession
Zav. Lab.	Zavodskaya Laboratoriya	Factory Laboratory
Zhur. Mikrobiol., Epidemiol. i Immunobiol.	Zhurnal Mikrobiologii, Epidemiologii i Immunobiologii	Journal of Microbiology, Epidemiology, and Immunobiology
Zhur. Nevropatol. i Psikhiat.	Zhurnal Nevropatologii i Psikhiatrii imeni S. S. Korsakov	S. S. Korsakov Journal of Neuropathology and Psychiatry
Zhur. Obshchei Biol.	Zhurnal Obshchei Biologiya	Journal of General Biology
Zhur. Vysshei Nerv. Deyatel.	Zhurnal Vysshei Nervnoi Deyatelnosti imeni I. P. Pavlova	I. P. Pavlov Journal of Higher Nervous Activity
Zool. Zhur.	Zoologicheskii Zhurnal	Journal of Zoology

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